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ABSTRACT

This activity oriented environmental guide is the result of cooperative efforts of high school teachers, students, scientists, and technicians. The activities are divided into four chapters: Hydrologic Cycle; Human Activities; Ecological Perspectives; and Social and Political Factors. Each activity contains seven parts: an introduction; questions regarding the activity; equipment; procedures; results obtained by using the study; limitations and problems encountered with the activity; and an annotated bibliography. There are seven appendices at the end of the guide. The appendix includes a discussion of water quality parameters, aids to implementation, suggestions regarding limitations and inconveniences, suggestions related to evaluation, a bibliography, a water pollution and environmental glossary, and comments regarding laboratory and field safety. (RH)

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A Curriculum Activities Guide

to

WATER POLLUTION

and

ENVIRONMENTAL STUDIES

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
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SE 009 857

A Curriculum Activities Guide
to
WATER POLLUTION
and
ENVIRONMENTAL STUDIES

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Preface

There were many people who contributed to the completion of this guide. Special thanks go to Joseph Chadbourne, Headmaster of Tilton School, Tilton, New Hampshire, who conceived the original idea and secured the backing of the Ford Foundation, and Alan McGowan, Director, Center for the Biology of Natural Systems, who directed the workshops.

We are grateful to the Department of the Interior for their support, both technical and financial. Dr. Herbert W. Jackson, Chief Biologist, National Training Center; Mr. F. J. Ludzack, Chemist, National Training Center; and Mr. R. Russomanno, Microbiologist, National Training Center, provided checks on the technical accuracy of the aquatic biology, chemistry and bacteriology sections of the guide.

Bernard Lukco, Department of the Interior, has provided great help by coordinating our efforts with Washington. E. Girtsavage and D. Smith from the New England Basins Office of the Department of the Interior made available to us a great deal of information from their training program.

We are also grateful to the Millipore Co., Bedford, Mass., and LaMotte Chemical Co., Chestertown, Md., for their aid in supplying equipment to the workshops.

The following people were instrumental in organizing and conducting the workshops and in contributing to the success of the chapters in this guide: Philip Murphy, continuing program coordinator, Robert Touchette and William Schlesinger for Hydrologic Cycle, Raymond Whitehorse and Alan McGowan for Human Activities, Alan Sexton and Robert E. Graham for Ecological Perspectives, and John Hershey and Stephen McLoy for Social and Political Factors, Albert Powers, Alan Sexton, Philip Murphy, and Rodney Page for Appendix I.

A final thanks is due Susan Bailey who has been secretary to the program; her efforts to keep things rolling smoothly have greatly aided everyone concerned.

The participants in the program who provided thousands of hours of work and testing are listed on the following pages.

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8-4-70

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* 1969 Schools Under Ford Foundation Grant
**Schools Not Covered By Grants

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In the past few years the general public has become aware of the importance of our environment. Some have been sufficiently aroused to form conservation groups which have gained various successes throughout the country. However, with few exceptions, these groups are interested in short range projects such as stopping the construction of airports, the building of highways, or some other particular form of defacement of our environment. Such organizations have had short range successes but they may well lose the greater battle because they only concern themselves with particular immediate objectives. They are really only stopgap measures. There is no doubt that they are needed and should be supported, but for the most part they are not designed to attack the environmental problem at its roots.

As for the rest of the populace, it is as Thoreau observed, "they hesitate, and they regret, and sometimes they petition; but they do nothing in earnest and with effect. They will wait, well disposed, for others to remedy the evil, that they may no longer have it to regret."[1] We cannot afford to wait and regret any longer. By building an awareness of the environmental problems among the youth, we are building national awareness among future adults, which will eventually shift the social priorities toward a final solution. We feel that this program can do just that. Much of the work on this project was accomplished with the aid of a Department of the Interior grant and a Ford Foundation grant which made possible two summers of extended research and development at Tilton School in Tilton, New Hampshire. These two grants allowed us to gather teachers and students from around the country and test their ideas, their methods and their approaches to the various problems encountered in such an endeavor. This guide is a result of their efforts.

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[1] Thoreau, Henry David, "Civil Disobedience," Thoreau, ed. by J.W. Krutch, Bantam Books, Inc. (1965, N.Y.), p.89.

The results of these two summers of research were unique in many ways. A basic assumption underlying this program is that the inherent curiosity which students possess can be effectively channeled into productive activity. Productive activity means more than what students can cover in a course; it means through the process of learning students can make a significant contribution to the society at large.

There is a desire on the part of students today to be directly involved in their society. This program is intended at least to both answer and capitalize on that desire. In order for this to occur, we must become aware that learning is not something that can transpire only in special places called classrooms. As one student remarked, "You actually learn by going out and doing what you are learning in theory, which is something I never did before." Stepping outside the classroom or expanding the classroom to encompass the life space of the student is an important aspect of this approach. For it is only there and then that the theory or disjointed, "irrelevant" facts begin to assume importance for the student.

For this reason, this guide is primarily activity orientated. As you read through this guide, you will notice that it is composed of various suggested activities which students may undertake. In most cases these activities require an hour and one-half to complete, however, some are included which require considerably longer periods of time for completion.

Each of these activities is written according to a format which includes the seven parts. The introduction, which briefly describes the activity, suggests the age or grade range for which the activity is best suited. Here you will also find any special equipment or requirements necessary to complete the activity are listed.

Part II consists of a series of questions which the teacher may pose to the students. These help in focusing student interest on the activity and are divided into several categories to provide a sequence of inquiry. The questions are grouped as follows:

a. questions which lead to the activity,
b. questions which initiate the activity,
c. questions which continue the activity, and
d. questions which help the teacher evaluate the students' efforts.

Sections III and IV of the activity sheets deal with equipment and procedure respectively. The experiment necessary to complete the activity is listed as well as are outlines of events which will probably take place. If branch points are likely, as is often the case, they are indicated. The teacher should try not to steer the activity in one set direction, but rather be ready and willing to allow students to pursue these branch points even if it means that the goal of the original activity is lost for the time being.

The next section on past studies highlights results obtained by using the activity. The activities which have survived the test of practical application should reinforce the teacher's efforts to use them again. Also helpful in this section are descriptions of how the students were evaluated and what outgrowths stemmed from the activity.

A section on limitations has been included for the benefit of the user. Here, the various problems likely to be encountered are listed. Limitations such as costs, extra prep time, and transportation should be well understood before the activity is used. If any of these limitations appear to create obstacles which in your particular case might inhibit the implementations of the activity you may find some helpful suggestions in Appendix 2 entitled Implementation.

The last section of each activity contains an annotated bibliography of references which are especially helpful in that activity. Organizations from which you may obtain continuing or new information are also noted here.

All of the activities contained in this guide have a common goal which is to embark the student in a path of inquiry which will eventually lead him to acquire the knowledge, and skills needed to accomplish his original activity. Once the interest and curiosity of the student is aroused through direct observation and questions, he will be stimulated to proceed to other activities which are related to the first. In this way, the student sees that the problems of environmental pollution are multi-faceted. The activities contained in this guide are concerned with only one aspect of the environmental problem: water pollution. It is difficult, if not impossible, to study water pollution without branching out into other types of pollution as well. Suppose for instance you decide that you can classify types of pollution into four areas: air, water, sight and sound. A polluted lake, rive or stream might have an offensive odor and be ugly to look at as well as contribute to air pollution.

Just as one cannot isolate a particular type of pollution from the rest, nor can one limit an investigation of water pollution to a specific academic field of inquiry. If our environmental problems are to be solved by the youth of today, they must understand the problem in all of its manifestations. This means that any understanding of the problem must eventually be interdisciplinary in nature. It must take into account the social and political as well as the scientific aspects of the problem. It will, therefore, encompass not only the Biology, Chemistry, Mathematics, and Physics departments, but also the Social Studies, History, English and Art departments as well.

It may occur to some teachers that arousing the interest of his or her students in their course material is what they have been attempting to do all along with only moderate success. This program is designed to allow the teacher to "run with" the particular interests of his or her students as they already exist rather than trying to create it where it doesn't. It may require the teacher to focus and even channel that interest, however this task is possible if difficult; the other is difficult if not impossible.

For example at Germantown Academy five or six students who were ordinarily occupied with concerns such as dress code, gym requirements and the usual assortment of student-faculty-administration problems turned their efforts to water pollution problems. A day or two of effort convinced them that a plan to descend on Harrisburg, Pa., the state capitol, was premature. They realized they couldn't lobby for something they knew nothing about. Approximately forty students joined the lobby to research the history of the industrial and community polluters. Groups of students untangled the local, state, and federal agency and legal structure to see where pressure could be applied. Several articles and papers were written to communicate the situation to others. The lobby is part of the life of the school and an action program is underway. The students are benefiting by having important successes in research, writing, and learning to live with others.

The significance of this is not so much that the students covered material which they may have covered in the course anyway, but rather that they sought out the material themselves. One can also begin (from this example) to understand the built-in circularity of this teacher's guide. It is possible to begin virtually anywhere in the guide and eventually, through a natural progression and through the use of the channeling questions contained in it, cover all of the activities contained in it. However, it should again be stressed that the activities are only intended as a guide; they are not exhaustive and should not be considered as a self-contained curriculum. In fact many of the activities are open ended, and may lead to results not suggested or even envisioned by their original purpose, as was often the case at Tilton School.

The activities are divided into four chapters. The activities contained in Chapter 1 deal with the hydrologic cycle; Chapter 2 considers human activities. Chapter 3 considers ecological perspectives and Chapter 4 examines the social and political factors involved in water pollution. This organization is helpful in approaching water pollution on an interdisciplinary level. In Chapter 1 the student learns about the natural processes involved in the hydrologic cycle. The activities in Chapter 2 are concerned with human activities which have a direct effect on that natural cycle.

Chapter 3 contains activities which relate human activities to biotic and abiotic aspects of ecosystems. Chapter 4 examines the social and political factors which overlay the scientific nature of ecosystems. By considering the means man has to effect changes to improve his environment, students learn to understand and contribute to that process.

There are seven appendices at the end of the guide which are invaluable to teachers and administrators using this guide. Appendix I, Water Quality Parameters, is an explanation of the chemical, bacteriological, and aquatic biological factors under consideration in the techniques called for in the activities. It also contains descriptions of techniques that are employed with commercial equipment and alternative procedures for use with equipment normally available in high school laboratories.

Appendix 2 considers the various problems one might expect to encounter in implementing this program. It offers some possible solutions and techniques for alleviating expenses, and possible sources of help. The information contained in this appendix is of particular interest to administrators.

Appendices 3 and 4 contain helpful suggestions for the teacher on limitations and evaluation respectively. The limitations section is intended to make the teacher aware, and thus able to prevent, the little inconviencies which are apt to affect the smooth flow of the activities. The evaluation appendix explains how behavioral objective methods apply to these activities.

There are three other appendices which the teacher will find particularly helpful. Appendix 5, bibliography and resources may be duplicated and simply handed to the librarian. Appendix 6, Water pollution and Environmental Glossary, is an in-depth compilation of terms from aquatic, ecological, hydrologic, and chemical fields. Appendix 7, Laboratory and Field Safety, may also be duplicated and handed to students.

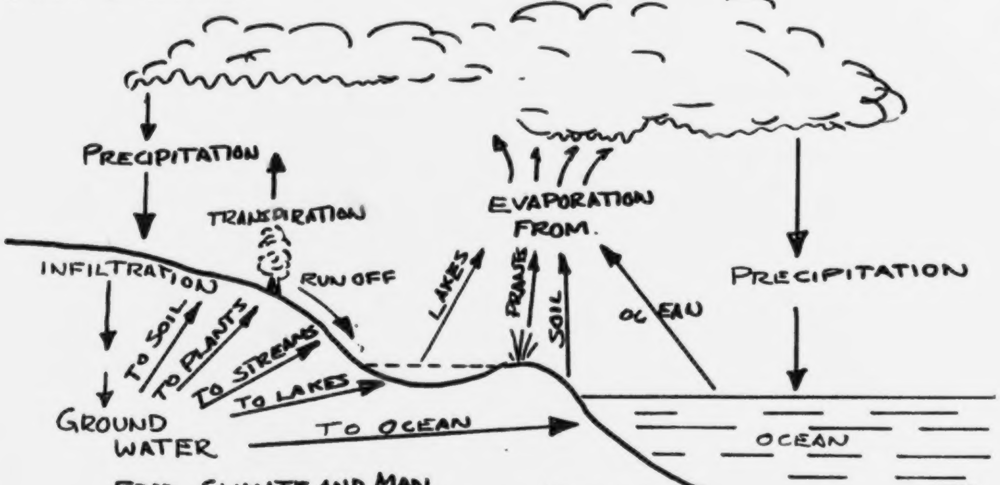
In order for this program to be considered a successful step toward the solution of our nation's environmental problems, it must be exported to as many schools as possible. The program could be considered a limited success in that those teachers and students who participated in the Tilton School program were overcome with the atmosphere which pervaded these two summers. They encountered numberous failures and frustrations which manifested themselves in a variety of ways. There were several cut feet and many shivering bodies which developed colds. There were philosophic clashes and leaky hip boots, heated discussions over results and methods, and one burned hand. However, pervading all this there was a shared knowledge that something was happening. One could stop in the middle of all the activity and realize that people, students and teachers alike, were involved in a very gratifying learning experience. Hopefully this teaching guide will act to stimulate similar experiences.

Chapter 1 Hydrologic Cycle

Draft

Water, one of mans most valuable resourses, moves continually through a cycle from the atmosphere to the earth, over and through the earth, and to the atmosphere.[1] Water quality changes as water moves through the cycle; therefore, an understanding of the cycle enhances an understanding of water pollution and its prevention. Climatology, geology, geography, and petrology, areas of study related to the hydrologic cycle, also aid in this study.

The hydrologic cycle, illustrated in Figure 1-1, shows many repositories for water and the processes which convey the water from one point to another.


PRECIPITATION
TRANSPIRATION
INFILTRATION
RUN OFF
TO SOIL
TO PLANTS
TO STREAMS
TO LAKES
TO OCEAN
GROUND WATER
EVAPORATION FROM.
LAKES
PLANTS
SOIL
OCEAN
PRECIPITATION
OCEAN
J.T.H.

FROM CLIMATE AND MAN
1941 YEARBOOK OF AGRICULTURE

Figure 1-1 Hydrologic Cycle Schematic

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[1] Stream Flow Measurements, Records and Their Uses, Grover and Harrington, Dover Publications, New York , 1966, page 1.

Hydrologic Cycle

The flow of water is made up of many smaller cycles. Rain water can run off into streams and rivers finding its way to the ocean or it can infiltrate the soil or farther downward to become ground water or part of the water table. Water can find its way back to the surface in many ways: it can seep into lakes and streams which are deep enough to extend into the water table; it can surface through springs or wells; it can flow from faults where the underlying strata becomes exposed; or the roots of plants can tap it.

Transpiration, the giving up of water vapor to the atmosphere by plants, and evaporation from land and water bodies also returns water vapor to the atmosphere. The cycle continues when pure water condenses and becomes precipitation.

The cycle is a global cycle but it can be studied in small regions by measuring inputs and outputs of water from these areas.

As water flows through the various pathways of the hydrologic cycle, its quality is often affected. It may pick up nutrients or pollutents in the form of dissolved solids as it passes through the soil or underlying rocks of a region. While it is in vapor form, chemicals and particulate matter in the air often becomes attached to or dissolved in it and precipitate to the ground. Evaporation and transpiration and purification processes which release water vapor back to the air.

Man affect the hydrologic cycle at many points. Man's pollution of the air adds to the chemical composition of the rain water. Run off from fields and gardens often carries nutrients and pollutants from fertilizers, pesticides, and animal wastes. Effluents which man adds to rivers and other waterways have a direct effect on the hydrologic cycle. When the flow of water through a system is studied it is also convenient and necessary to study the flow of nutrients and pollutants which accompany the water.

In this section, the activities focus on parameters of the hydrologic cycle and lead to investigations which allow students to evaluate the total system within a given region. Such evaluations are referred to as calculating a total budget for a locale. Such activities show that the inputs minus the outputs of water containing nutrients and pollutants.equals the change of storage within the sytem.

Activities are designed on two levels. The basic level is designed to give the student an understanding of the water flow through an area of the cycle. The advanced level gives an understanding of the nutrients and pollutant flow shich accompanies the water. Generally suggestions for maintaining and continuing activity are concerned with the physical and biological characteristics within the system and lead to man's effect on the system.

Inherent in the following activities is the need for the deliniation of a location for study. Any study region is possible provided its boundaries are carefully defined. Boundaries include the air above and a specific depth in the ground below unless a smaller region is chosen. A conceptual diagram of the hydrologic cycle of an area of study is outlined on the next page.

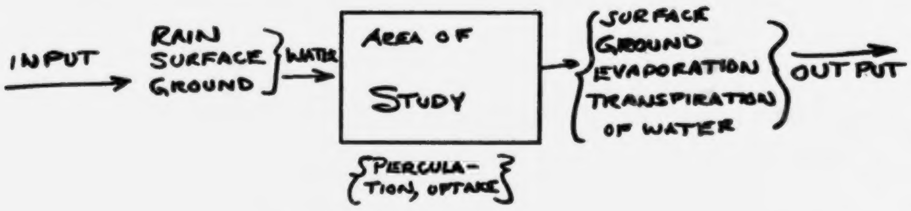
INPUT
RAIN
SURFACE
GROUND
WATER
AREA OF
STUDY
SURFACE
GROUND
EVAPORATION
TRANSPIRATION
OF WATER
OUTPUT
PERCULATION, UPTAKE

FIGURE 1-2

There are few limitations associated with the activities of this section. Most can be carried out by a teacher in any situation. They are capable of being performed on driveways, lawns, football fields or in country watersheds. The activities do not encompass all aspects of the water cycle.

The following skeleton questions serve to outline the scope of the section:

1. How much precipitation falls on a particular area? Is it pure water?
2. What happens to the precipitation that falls on soil? Where does it go? How does it change?
3. What role do plants have in the hydrologic cycle?
4. What is the source of water in streams? Does this water naturally contain any nutrients?
5. What is the water and nutrient budget for your study area?

The following resources will be found useful throughout the entire section. Resources of particular interest are listed at the close of each activity.

Bruce, J.P. and R. H. Clark, Introduction to Hydrometeorology, New York: Pergamon Press, 1966.

Chorley, Richard J. (Editor), Water, Earth and Man, London: Methuen and Co. Ltd. 1969. Available in the U. S. from Barnes and Noble Inc.

Life Science Library, Water, New York: Time Inc. 1966.

Thomas, H.E., Water, Washington: U.S. Government Printing Office, 1955. Yearbook of Agriculture.

Ward, R.C. Principles of Hydrology, New York: McGraw Hill Pub., Co., 1967.

A Surface Runoff

I Introduction

The purpose of this activity is to exaine surface runoff and its relation to the hydrologic cycle. The activity can be performed by a wide range of grade levels and in many types of study sites.

II Questions

1. To lead into the activity, ask students:
   a. What happens to the precipitation that falls onto the ground?
2. To initiate the activity, ask students:
   a. Is it possisbe to collect precipitation after it strikes the ground?
   b. Will some of this precipitation be on the surface?
   c. What is the effect of various surface slopes?
3. To continue the activity, ask students:
   a. What is the chemical composition of surface runoff water?
   b. What is the effect of intensity of precipitation?
   c. What is the effect of soil moisture?
4. To evaluate the student, consider?
   a. With the limitations involved, did the student's method eliminate as many external variables as possible?
   b. How accurate were the measuring techniques?

  c. Did his simulated rain approach a natural condition?
  d. Did the student relate this exercise to the hydrol-cycle and water quality?
  e. Did the student realize that runoff is only one "fate" of precipitation water which strikes the ground?

III Equipment

1. Shovel
2. Standard size watertight dust pan or some similar water collecting device.
3. Several number ten cans at least one of which is marked off in liters and another with holes in the bottom for simulated rainfall.
4. A 200 ml beaker.
5. Meter stick or ruler
6. Brunton compass or clinometer (Homemade device for measuring slope is also possible)
7. Funnel and filter paper
8. Flask

IV Procedure

1. Basic Level:
   a. Select a site with a variety of slopes.
   b. Determine an area of 20 cm square and excavate a shallow trench on the downhill edge for the runoff collecting device (dust pan, tray, etc.).
   c. Measure angle of the slope with the Brunton compass

or clinometer.

- d. Pour one liter of water into a #10 can with holes while holding over the delineated area.
- e. Filter surface runoff collected and measure the volume to get percent of runoff.
- f. Wait five minutes and repeat process to get the effect of increased soil mositure.
- g. Select and delineate an adjacent area or similar site with the same slope. Repeat the process using a different intensity of simulated rainfall.
- h. Repeat and process in areas of differing slope.
- i. If further studies are desired, repeat the process using different soil type and vegetation.

2. Advanced Level
   - a. Collect (as before) the runoff from various sites showing differences in ground cover, slope etc.
   - b. Using a chemical testing kit, determine and compare the nutrient content of the runoff from these areas.
   - c. Correlate variable physical and enviromental factors with changes in water quality of surface runoff.

V Past Studies

1. Students have found that the moisture of the soil from previous precipitation can have an effect on the amount of runoff.
2. Students have conducted this activity on driveways, near

farm fields and in various other areas, and have seen the effect of automobile emissions, animal wastes and fertilizers on surface runoff composition.

VI Limitations

1. Even distribution of simulated rainfall may be difficult to reproduce.
2. In order to cover many variables, teachers may find it convenient to break their class down into small groups, having each assigned an environmental or physical variable to examine, and to pool data later.

VII Bibliography

Earth Science Curriculum Project, Investigating the Earth, Boston: Houghton Mifflin Co., 1967. Chapter 9 contains a discussion of the movement of surface and ground water.

Ward, R.C., Principles of Hydrology, New York: McGraw Hill Publishing Co., 1967. This more advanced text gives a stimulating and complete discussion of surface runoff and its relation to the hydrologic cycle.

B Infiltration and Percolation: Concepts and Measurements Involved.

I Introduction

This activity aquaints the student with the action of water absorption, infiltration and percolation in soil and encourages him to relate these to the hydrologic cycle and water quality. The basic level activity may be carried out by seventh graders and older; the advanced level may be carried out by students who have a little knowledge of chemistry. The activity will be carried out in a field or on a lawn where digging holes temporarily is permissible.

II Question

1. To lead into the activity ask the students:
    a. What happens to the precipitation that falls on soil?
    b. Where does the water in the soil move and how does it change?
    c. What is the action of water that enters soil?
2. To initiate activity ask the students:
    a. How would you determine water motion within the soil?
    b. What determines the direction of water motion? What effect does this movement have on water quality?
3. To continue activity ask the students:
    a. Are there any differences in the speed of water motion?
    b. Is there any upward or sideward movement?

c. Does soil type affect the motion or effects of water in soil?

4. To evaluate the student's performance consider:
    - a. Has he demonstrated soil water movement satisfactorly
    - b. Was he able to relate infiltration to possible change in water quality?
    - c. Does he explain where much of the water he uses goes?
    - d. Is he concerned as to the effects of the use of trace dye?
    - e. Does he relate man's activities to a possible role in the quality of infiltrated water.

III Equipment:

Basic Level

- a. Digging tools
- b. Non-toxic dye such as fluorescent Pyla-Tel tracer dye? (Food coloring is also possible)
- c. 10 qt. buckets and other large containers
- d. Timing instruments
- e. Meter Stick
- f. Filter paper, Kleenex, paper towels, or toilet paper
- g. Aluminium edging fence

2. Advanced Level

   a. Non-poisonous leaching chemical such as sodium phosphate
   b. Funnels
   c. Sample Bottles
   d. Hach, Delta or LaMotte kit or suitable qualitative chemistry testing kit.
   e. Soil collection bags
   f. Beakers
   g. Pipettes and rubber tubing

IV Procedures:

1. Basic Level

   a. Have students set up a thirty centimeter circle of aluminium edging fence.
   b. Have students calculate how long it takes for a given quantity of water to penetrate the soil after it is poured into the enclosed area.
   c. Have students compare times from various areas.
   d. Have students excavate a 15 centimeter diameter hole 30 centimeters or more deep.
   e. Have students excavate smaller holes around the original hole at various distances from it.
   f. Have students fill the original hole with the tracer dye solution.

g. Have students make periodic checks in the surrounding holes with absorbent papers to determine flow of water, and dye.

2. Advanced Level

a. Have students excavate an additional experimental hole and distribute a known quantity of the non-toxic soluble chemical at the base of this hole.

b. Have students add enough water to bring the concentration of the solute to 0.1M in the hole.

c. Have students excavate test holes around the original at various intervals.

d. After appropriate time delay, have students collect moist soil or accumulated water smaples from the surrounding holes. These can be placed in bags and collection can be facillitated with tubing and pipettes.

e. Have students test these samples with chemical testing kits, using the test appropriate for the test chemical used. This can be a qualitative or quantitative consideration. The student should test control samples from the same area.

f. Have students compare and contrast their results.

V Past Studies

Past studies show flow through the soil test holes will be enhanced if they are placed on an incline.

VI Limitations:

This activity can be done almost anywhere with simple equipment depending on a teacher's resources.

Surrounding holes can be done with an auger and be much smaller if time saving is a factor. Do not place the surrounding holes too far from the original. Please be sure to get permission of property owners before you go to work.

VII Bibliography:

Strahler., A., Physical Geography (2nd ed.) John Wiley & Sons,
New York, 1960

This text contains good information on Hydrologic cycle & Infiltration with Diagrams.

Monkhouse, FJ., A Dictionary of Geography
Arnold, London, 1965

Gives dictionary meanings of leaching Infiltration etc. as
they pertain to geography

U.S. Dept. of the Interior, A primer on Water 1960

Very good information on runoff & infiltration under different conditions

C Transpiration: The Concepts and Measurements Involved.

I Introduction

This activity enables students to acquire an understanding of transpiration and its relationship to the hydrologic cycle. Seventh graders and above may complete this activity on the basic level.

II Questions

1. To lead into activity ask students:
    - a. What is transpiration and how does transpiration relate to the hydrologic cycle?
2. To inititate activity ask students:
    - a. Can a way be devised to measure the rate of transpiration and determine the factors that limit it?
    - b. How accurate is this method?
3. To continue activity ask students:
    - a. How would the transpiration rate change in relation to changes in physical factors and mans activities such as air pollution.
4. To evaluate the students performance consider:
    - a. Did the students gain an understanding of the transpiration process?
    - b. Did the students devise new techniques for demonstrating transpiration?
    - c. Did the students relate the process to the hydrologic

cycle?

III Equipment

1. Basic Level:
    - a. Small potted plant
    - b. Bell Jar
    - c. Flat surface for bell jar such as a glass plate
    - d. Plastic sealable bags
    - e. Small graduated cylinder
    - f. Sensitive balance or scale (± 0.1 g.)
    - g. Vaseline
2. Advanced Level:
    - a. 500 ml Erlenmyer flask
    - b. 2 hole rubber stopper to fit flask (slit one hole to side of stopper)
    - c. glass tubing
    - d. 20 cm. of rubber tubing
    - e. Small leafy plant
    - f. 1 ml. pipette
    - g. Burette clamp
    - h. Ring stand
    - i. Timing device

IV Procedures

1. Basic Level:
    - a. Have students place a potted plant under a sealed

bell jar.

b. Have students make observations for a short period of time.

c. Have students alter some physical factors and make new observations.

d. Record and discuss all observations.

or,

a. Have students find a tree with leaves low enough to reach.

b. Have each student enclose a leaf with a plastic bag.

c. Have students wait an appreciable amount of time and collect bags.

d. Have students quantitatively determine the amount of water transpired.

e. Have students record and compare results. Ask them where the water came from and where it goes.

2. Advanced Level:

a. Have students set up apparatus as outlined in figure 1-1.

b. Have students fill the system completely with water and record the quantity of water used by the plant at various intervals.

c. Have students graph the data.

d. Have students repeat the experiment altering some physical factors.

e. Have students outline the relationship of physical factors to transpiration.

V Past Studies

1. Students on the elementary and early secondary levels marveled at the collection of water by encloseing a leaf in a plastic bag.
2. Students at the tenth grade level were excited to find that plants give the atmosphere such a large quantity of water. One student devised a quantitative method to measure the amount of water a tree transpired in 24 hours.
3. Students at the tenth grade level were able to quantify the difference in transpiration between shaded and unshaded leaves and leaves of different sizes.

VI Limitations

There are no limitations forseen. Teachers should caution their students that procedures calling for sealed containers should be closely followed.

VII Bibliography

Biological Sciences Curriculum Study. High School Biology, Green Version. Second Edition. Chicago: Rand McNally & Co. 1968.

An easy reading basic biology text. Transpiration is treated on pages 447-449 and includes detailed procedure for a laboratory investigation of transpiration. 803 pp

De Wiest, R.J.M. Geohydrology. New York: John Wiley and Sons, Inc. 1965.

A highly technical treatment of all aspects of the engineer's concerns, however, the treatment of transpiration is brief, simple, and useful. (See pp. 47-49) 360 pp

Leopold, Luna and Walter Langbein. A Primer on Water. Washington, D. C.: Superintendent of Documents, U. S. Government Printing Office. 1960 50 pp.

A simple pamphlet with good diagrams well worth having in the classroom. Runs the gamut from the water cycle to water purification systems, farm irrigation, and legal aspects. Water in relation to plants and soil is treated on pages 26-27.

Morholt, Evelyn, Paul Brandwein, and Alexander Joseph. A Sourcebook for the Biological Sciences. Second Edition. New York: Harcourt, Brace & World, Inc. 1966. 752 pp plus detailed index.

A must for every biology teacher. Use in this activity for directions for demonstrating transpiration and plant physiology.

U. S. Department of Agriculture. The Yearbook of Agriculture, 1955: Water. Superintendent of Documents, U. S. Government Printing Office. 1955. 723 pp plus index.

An excellent reference for the price ($2.00). Deals with water in connection with agriculture, forestry, and wildlife. Easy reading. Good diagrams. Lots of Statistics, though a bit old now.

Hill, Popp, and Grove. Botany. New York: NcGraw-Hill and Co.

A collegiate text, but easy enough for the good high school student. There are references to the physiological aspects of transpiration.

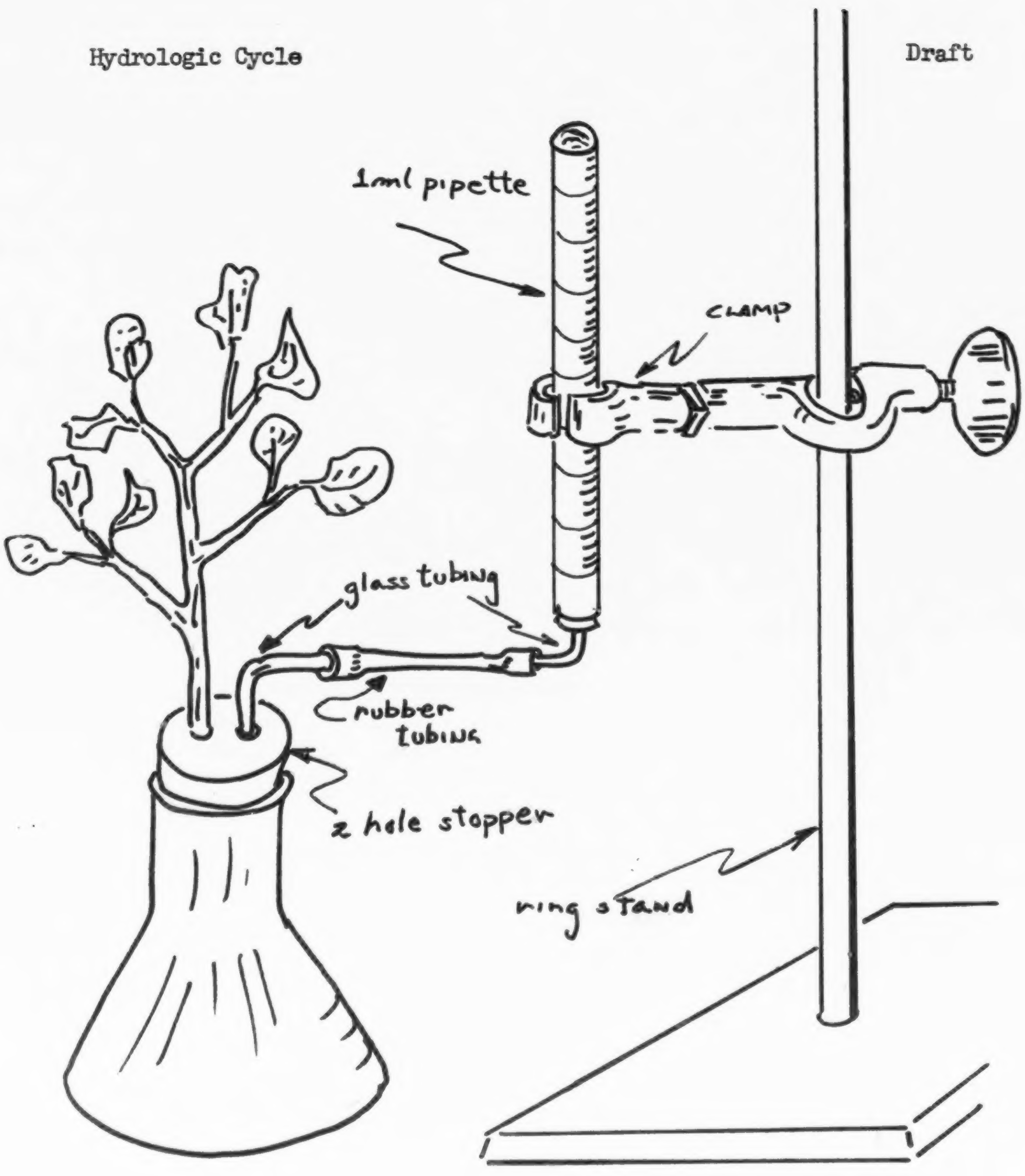
1ml pipette
clamp
glass tubing
rubber tubing
2 hole stopper
ring stand

Figure 1-1 DIAGRAM FOR ADVANCED PROCEDURE

D Soil Evaporation and Transpiration.

I Introduction

The purpose of this activity is to provide the student with an understanding of transpiration and its relation to soil moisture content. It is applicable to a wide range of grade levels and study areas.

II Questions

1. To lead into the activity ask the student:
   - a. What happens to the water taken up by plant roots?
   - b. Where does it come from?
   - c. Where does it go?
2. To initiate activity ask the students:
   - a. Does the use of soil water by plants have any effect which can be measured in terms of a difference in soil moisture content in a vegetated and unvegetated area?
   - b. Does a covering of plants have any effect on the evaporation of moisture from soil?
3. To continue the activity ask the students:
   - a. How might man's land use activities effect the hydrologic cycle through an effect on plants and their transpiration?
   - b. Is transpiration a "good" or "bad" thing in relation to the role of water in our lives?

relation to the untreated leaf and relate this to the biological role leaves play in transpiration and the water cycle.

or

1. Have students clear the vegetation on a square of ground 30 cm on a side?
2. Have students take soil samples at various depths
3. Have students determine the moisture content of these samples by weighing, drying and reweighing.
4. The next day, have students take three more samples from the denuded plot and 3 from a vegetated area near by.
5. Have students determine moisture content of each.
6. Have students discuss the results in terms of the hydrologic cycle and transpiration.

or

1. Have students place an equal amount of soil in each of 6 juice cans.
2. Have students add an equal amount of water to each and plant seeds in two of them.
3. Have students cover all the cans with plastic.
4. When the seeds begin to germinate have students uncover- the cans with planted seeds and two of the other cans.
5. After three days of plant growth, remove the plants and take an equal weight of soil from each of the cans and

4. To evaluate the student's performance consider:
   a. Does he weigh the idea that vegetation inhibits precipitation runoff with the idea that vegetation increasss depletion soil moisture by transpiration?
   b. Does he realize the multi-role of plants in the hydrologic cycle.

III Equipment:

1. A coleus or geranium plant
2. Vaseline
3. Soil auger'
4. Plastic bags (sandwich bags are excellant)
5. Trowel or small shovel
6. Balance
7. Meter Stick
8. Oven or drying device
9. _6_ Tall juice cans
10. Masking tape
11. Seeds of a convenient plant

IV Procedure

1. Have the students pick four leaves from the plants
2. Have the students coat the top side of one leaf, the bottom of another and both sides of a third with vaseline.
3. Have students check the leaves in 24 and 48 hours.
4. Have students discuss the condition of the leaves in

determine its moisture content.

6. Have students compare the moisture contents of each and discuss the mechanisms which cause different moisture contents in each of the three type of "can" situations.

V Past Studies

1. Students have been graphically able to show that woil loses more water when vegetated than it does in a denuded area where only evaporation takes place.
2. Students have often been stimulated to argue whether the role of plants is important in the hydrologic cycle. Replacement of atmospheric moisture must be weighed with the importance of soil moisture to man.

VI Limitations

There are no forseeable limitations in this exercise although some parts extend over a lengthy time period. A site location and materials collection should be no problem.

VII Bibliography

Biological Sciences Curriculum Study, High School Biology, Green Version, Chicago: Rand McNally & Co. 1968. This text provides an explanation of transpiration and ideas for developing other demonstration projects.

Leopold, Luna and Walter Langbein, A Primer on Water, Washington: U.S. Government Printing Office, 1960. An excellant pamphlet which deals specifically with the relation of plants, transpiration and soil moisture.

Morholt, E., Paul Brandwein, and A. Joseph, A Sourcebook For the Biological Sciences, New York: Harcourt, Brace & World, Inc. 1966. This reference treats the physiology of transpiration.

Ward, R.C., Principles of Hydrology, New York; McGraw Hill Publishing Co., 1967. This advanced but excellant text gives a complete and stimulating coverage of transpiration and its relation to the hydrologic cycle.

Wilson, Carl and Walter E. Loomis, Botany, New York: Holt, Rinehart and Winston, 1962. A standard reference for botany, this text treats the biology of transpiration.

E. Evapotranspiration Activity.

I Introduction

The purpose of this activity is to show that on a small grassy area water leaves the grass and enters the atmosphere by the process of evapotranspiration. It is a suitable activity for a beginning study of the hydrologic cycle. Seventh grades can easily do this study and young-students will enjoy it if the teacher helps with the water testing.

II Questions

1. To lead into the activity ask students:
   a. Have you ever noticed water collecting on the underside of a waterproof material after it has been on the ground?
   b. Where did this water come from?
2. To initiate activity ask students:
   a. Can you collect and/or measure the water from the underside of a waterproof material after letting the material lie on a grassy area in the sun?
3. To continue the activity ask students:
   a. How does the process of transpiration fit into the hydrologic cycle?
   b. Do you think transpired water is pure?
   c. Is this important?
4. To evaluate the students performance consider:

a. Does the student seem to understand the concept of transpiration and its relation to the hydrologic cycle?

b. Did he develop additional approaches and techniques for demonstrating and measuring transpiration?

III Equipment

1. A plastic sheet (Preferably mounted on a stiff form. A form cut from a cardboard box and a clear sheet of plastic or cellophane stapled to its edges works well).
2. A small container to collect water from the plastic.
3. Water testing Kit for advanced study.

IV Procedure

1. Place the collecting equipment on grass, preferably in sunlight and leave it there for 30 minutes or more.
2. Collect or observe droplets of moisture which have collected on the underside of the plastic.
3. If enough water is obtained, chemical testing procedures may be employed to determine such factors as total dissolved solids.

V Past Studies

Students in many situations have been able to appreciate the demonstration of transpiration and its relation to the water cycle by using this experiment.

VI Limitations

There are no limitations seen in this experiment.

VII Bibliography

Earth Science Curriculum Project, Investigating the Earth, Boston: Houghton Mifflin Co. 1967. This standard text gives a short treatment of transpiration on page 215.

Ward, R.C., Principles of Hydrology, New York: McGraw Hill Purblishing Company, 1967. This excellant text gives a coverage of evapotranspiration and its relation to the hydrologic cycle. Many ideas for continuing study projects can be found.

Wilson, Carl and Walter E. Loomis, Botany, New York: Holt, Rinehart and Winston, 1962. A standard botany text, this source covers the biology of transpiration.

F. Infiltration: Its Effect on Water Quality.

I Introduction

This activity demonstrates the change in precipitation water quality as it passes through soil using a lab model. This activity is applicable to a range of grade levels. Seventh graders can complete this activity if the teacher assists with the dissolved solids tests. Students with some chemistry background can do the activities themselves.

II Questions

1. To lead to the activity ask:
   a. What happens to rain water after it strikes the soil?
   b. Does some soak in?
   c. Does this change its quality?
2. To initiate the activity ask:
   a. How any quality change that occurs during infiltration may be measured.
3. To continue the activity ask:
   a. What would the variance in change be if two samples of different soil composition were tested?
   b. What would happen in test areas of different vegetation?
4. To evaluate the student's performance consider:

a. Was he effective in using testing equipment and becoming adapted to testing techniques?

b. Was he able to decide on logical choices for dissolved solids tests for his type of soil?

c. Was he eager to improve on the experiment and make attempts to devise new experiments for testing changes in precipitation water quality.

d. Did he check the distilled water to find its pH and if any minerals were already present.

III Equipment

1. Chemical testing equipment
2. Sample box with screened bottom
3. Shovel
4. Collecting pan
5. Rain water or distilled water
6. Number 10 can
7. Funnel (optional)
8. Ringstand (optional)
9. Funnel holder (optional)
10. Filter paper (optional)
11. Beakers (optional)
12. #10 nail or punch.

IV Procedures

1. Take a soil sample from the area chosen for study. Soil samples can be up to one cubic foot (30 - 45

kilograms). Bring the sample back to the lab.

2. Spread the sample in the sample box with the screened bottom.
3. Make a rain simulator by taking a number 10 can and perforating the bottom with a nail or punch.
4. Measure out one liter of the test water.
5. Simulate rain on the soil sample by pouring your liter of water into the perforated can and collecting the seepage in a collection pan placed below the screened box.
6. Do appropriate dissolved solid tests on the seepage collected.

V Past Studies

1. Some students recorded high iron and cop per content in seepage water until they realized that their screening was affecting their results.
2. Students discovered that filtering seepage resulted in facillitating colorimetric chemical testing.
3. Some students have used rainwater in conducting the experiment. By testing water quality of rain water and seepage, a more realistic presentation of the effect of infiltration on water quality was found.

VI Limitations

1. This exercise requires a general knowledge in recognizing dissolved solids and testing for them. Teachers

should let their students decide on the appropriate dissolved tests for the soil sample collected.

2. Careful rain simulation is necessary for realistic and uniform distribution.
3. Sites should be chosen that are representative and easily accessible.

VII Bibliography

Leopold, Luna B. A Primer on Water, Washington: U.S. Government Printing Office, 1960. This inexpensive pamphlet contains a good description of infiltration in various conditions.

Strahler, A.N., Physical Geography, New York: John Wiley & Sons, Inc., 1960. This reference contains good general information on the hydrologic cycle and infiltration diagrams.

Ward, R.C., Principles of Hydrology, New York: MCGraw Hill Publishing Company, 1967. An excellant general source, this text contains a detailed and stimulating coverage of infiltration and its relation to water quality and the hydrologic cycle.

G Ground Water Seepage

I Introduction

This activity demonstrates that rock and soil minerals are dissolved in water as it moves from the surface to ground water and to relate these nutrient changes to the water cycle. Students in a range of grade levels may complete this activity as the extent of testing is adaptable to the ability of the group. Any area where ground water seeps to the surface or is otherwise available for collection is a possible study site.

II Questions

1. To lead into the activity ask students:
   Does water quality change when it soaks into the ground?
2. To initiate the activity ask students:
   a. Where can we collect ground water samples?
   b. How can we determine the composition of the water quality change?
3. To continue the activity ask students:
   a. How does the change in water quality take place?
   b. If this type of solution continues, what will happen to the soil and rocks of the area?
4. To evaluate the students efforts consider:
   a. Has the student demonstrated how and why seepage water is of different composition than surface or

rain water?

b. Has the student made any reasonable conclusions as to where the dissolved materials in the seepage water will finally accumulate?

c. Does the student relate leaching to a role in the changing water quality and nutrient composition in the hydrologic cycle?

d. Does the student realize that infiltration can also be a water purification mechanism?

e. Does the student relate man's activities and their possible effect on the quality of ground water?

III Equipment

1. 5-10 Collection Bottles (Sterile and chemical)
2. Water chemistry testing kit (qualitative or quantitative)
3. Water bacterial analysis materials

IV Procedure

1. Select an area of rock or soil where seepage of ground water to the surface is evident.
2. Collect 5-10 bottles of water for water chemistry and bacterial tests.
3. Test the water qualitatively or quantitatively as time and resources permit.

V Past Studies

Students and teachers have found that if areas of ground water seepage are inaccessable that an examination of well or spring water is equally feasible.

VI Limitations

The major limitation of this activity is the determination of a site with suitable flow for study; however, such seepage is found throughout the country.

VII Bibliography and Resources

Baldwin, Helene l., *A Primer on Ground Water*, Washington: U. S. Government Printing Office, 1963. This is an excellent pamphlet for introductory treatment of ground water.

Ward, R. C., *Principles of Hydrology*, New York: McGraw Hill Publishing Co. 1967. This somewhat advanced text gives a complete coverage of ground water and contains ideas for stimulated students to develop into projects.

Teachers are also advised to contact their state and local Federal agencies for information on ground water resources of particular areas. The Soil Conservation Service is a particularly helpful agency.

H. Transpiration and Plant Uptake

I Introduction

This activity is designed to help students realize that water is being taken in and given off by plants as part of the water cycle. It can be carried out in varying degrees beginning at the first grade level. Few time and travel problems occur because local weeds, schrubs and trees may be easily found in the immediate area.

II Questions

1. To lead the activity ask:
   a. What happens to a plant if it is not watered?
   b. Why do plants have to be watered more than once?
   c. What is happening to the water?
2. To initiate the activity ask:
   a. How is water released from the plant and why don't we see it?
   b. How can we show that water is being given off?
   c. How can we measure how much water is being given off?
3. To continue the activity ask:
   a. If a small plant gives off a given amount of water, how much does an oak tree give off?
   b. How much would a forest give off in a certain time period?
   c. Are the biological activities of plants involved in pollution?

   d. Does a given plant give off an equal amount of water from day to day or under variable physical conditions?

4. To evaluate the student's performance consider:
   a. Did the student devise methods for measuring the uptake and release of water by plants?
   b. Were his techniques successful in visibly demonstrating transpiration?
   c. Did the student realize the role of plants in the hydrologic cycle and possible pollution from plants in a natural environment?

III Equipment

1. Plastic bags (one per student)
2. Twist wires for tightening bags around plant stems
3. Bucket
4. Graduated cylinder or some equivalent means of liquid measure
5. Spade
6. Aluminum foil

IV Procedures

1. Transpiration activity
   a. Locate a place on your campus where there are small plants with stems so structured that plastic bags can be slipped over the end. Weeds are ideal. (e.g.milkweed)
   b. Have each student slip his bag over the end of a stem so that it will cover as many leaves as possible. Use

the twist wires to tighten the open end around the stem securely.

   c. Have the students return the next day and cut off the stem with the bag on it. Bring it back to the classroom and measure the amount of water that has collected in the bag.

2. Plant Uptake Activity
   a. Have the students dig up two or more plants, getting as much of the root system as possible. Remove all soil from the roots and place each in a bucket containing a measured amount of water covering the roots.
   b. Have the students check the amount of water in the bucket at various later times.

V Past Studies

1. Students have found that they can demonstrate transpiration using a plant under a bell jar.
2. Although students at a particular school found that evaporation from all the plant uptake buckets was uniform, they devised a method using aluminum foil of eliminating evaporation as a variable.
3. Other students placed transparent plastic sheets on their lawn and observed the transpired water collecting under them.

VI Limitations

1. Teachers should try to prevent other students at the school from disrupting the transpiration experiment.

2. Teachers can avoid problems by locating suitable plants on their campus before the students begin work.

VII Bibliography

Biological Sciences Curriculum Study, High School Biology, Green Version, Chicago: Rand McNally and Co., 1968. Written for the high school level, this text contains a description of transpiration and ideas for further experiments.

Ward, R.C., Principles of Hydrology, New York: McGraw Hill Publishing Co., 1967. This excellant more advanced reference contains a stimulating discussion of transpiration and its relation to the water cycle.

Wilson, Carl and Walter E. Loomis, Botany, New York: Holt, Rinehart and Winston, 1962. A standard botany text, this reference contains information on the biology of transpiration.

I. Erosion: The effects of water on soil

I Introduction

The purpose of this activity is to demonstrate the effects of various types of soil and slopes on the erosion due to water runoff on an area. It is a possible beginning activity for students at any level of understanding and is capable of being performed on any nearby eroded area.

II Questions

1. To lead into the activity:
    a. Are there any hills or cliffs in your area that are being eroded?
    b. How does the runoff water effect these hillsides?
    c. Does the type of soil composition have any effect on the erosion rate?
2. To initiate activity:
    a. What types of soils are these hills composed of?
    b. What is the slope of these hills?
    c. How can we measure the ability of water to change the structure of different soils on a slope?
3. To continue activity:
    a. What types of plant life, if any, are found on these hillsides?
    b. Are similar types of plants found in all soil types?

  - c. How does plant growth seem to effect erosion?
  - d. How can the amount of rainfall be measured on individual hills?
  - e. How can erosion rates be determined?
  - f. What are other physical factors in erosion?

4. To evaluate the students' performance:
   - a. Were the students able to identify various soil types as to their resistance to erosion?
   - b. Were the students able to correlate slope to erosion?
   - c. Did the students recognize the forces other than water which act upon the soil?

III Equipment

1. rain guage
2. meter stick
3. protractor or clinometer
4. stakes
5. hammer

IV Procedures

1. Have students visit the erosion site and set up rainfall guage.
2. Have students drive measured stakes into the ground at the top, middle and bottom of the area.
3. Have students measure the slope of the area.

4. Have students describe the soil of the site.
5. Have students examine and describe the plant life of the area and the root structure of particularly abundant species.
6. After the next rainfall, have students visit the site and repeat the previous procedures.
7. Have students calculate the amount of soil eroded off a specific area using the comparative before and after measurements from their stakes.
8. Have students correlate the amount of rainfall, slope, vegetation, etc. with the amount of erosion.

V Past Studies

1. Students have often been amazed at the amount of soil which can erode off an unprotected hillside in a single rainstorm.
2. Some studies have included graphs correlating slope with amount of erosion.
3. Students have often been impressed at the amount of solid material that may enter a stream from such a hillside. The link between erosion and water pollution becomes visibly evident.

VI Limitations

1. Teachers may have difficulty finding a site suitable for study. Housing developments and road construction

areas can suffice, though open mining pits and rather steep unprotected hillsides usually provide the best study sites.

2. There are few other limitations to the study although the time period should be noted as this is a continuing study.

VII Bibliography

Ward, R.C., Principles of Hydrology, New York: McGraw Hill Publishing Co., 1967. This rather advanced reference contains a readable and stimulating treatment of water runoff.

Earth Science Curriculum Project, Investigating the Earth, Houghton-Mifflin Co., 1966. This text contains a description of water forces and their cause of erosion.

Coleman, Edward A., Vegetation and Watershed Management, New York: Ronald Press Co., 1953.

J. Diffusion: Demonstration of water's solvent and dilution properties

I Introduction

The purpose of this activity is to demonstrate the diffusion of materials in water. Being a lab activity it is easily applicable to most teaching situations and a range of grade levels.

II Questions

1. To lead into the activity:
   a. What is water?
   b. What is a solvent?
   c. What is diffusion?
   d. Is it possible to use elements, compounds or both to demonstrate diffusion and the rate of diffusion?
2. To initiate activity:
   a. How long does it take for differing chemicals to diffuse in water?
   b. Is there a differnece in their diffusion rate?
3. To continue activity:
   a. Is there a noticeable difference in diffusion of organic and inorganic chemicals in water?
   b. How do effluent wastes from man's activities diffuse?
4. To evaluate the student's performance consider:
   a. Did the student relate diffusion to water pollution?
   b. Did the student realize the importance of water's solvent properties in the hydrologic cycle and water pollution?

c. Did the demonstrate varying differences in diffusion rate of various test compounds he chose?

III Equipment

1. Suitable test chemicals such as potassium permaganate ($KMNO_4$), copper sulphate ($CuSO_4$), iodine and elemental iron.
2. Beakers and flasks
3. Effluent wastes from man's activities such as water from washing or cooking vegetables, sludge from a sewage plant, factory effluents from a local industries, animal wastes from barnes, detergents etc.
4. Stopwatch
5. Bunsen burner, ring stand, asbestos screen
6. Scale
7. Filter paper

IV Procedures

1. Add crystals or drops of test chemicals to beakers of water.
2. Observe and time the rate of diffusion throughout the solvent.
3. Have the students do the same with the various test effluents they have selected.
4. If students select a test material which does not completely dissolve, have them separate the undissolved material, dry and weigh it to determine the percentage of their material which has diffused.

V Past Studies

Students have easily been able to relate what they have seen in this activity in the lab to what they see as effects of man on local rive

VI Limitations

Teachers should caustion their students about the dangers involved in the use of sewage wastes

VII Bibliography

Earth Science Curriculum Project, Investigating the Earth, New York: Houghton Miffline co., 1966.

Leopold, L.B. and Kenneth S. Davis, Water, New York: Time Inc., 1968.

U.S. Department of Agriculture, Water, Washington: U.S. Goverment Printing Office, 1955.

K. Ground Water: An examination of the source of water in streams.

I Introduction

The purpose of this activity is to examine ground water as the source of water in streams. This activity is recommended for the high school level where it can be conducted successfully after the location of a small stream which is convenient for study. This activity requires more than an hour and one half to complete.

II Questions

1. To lead into the activity:
   - a. Where does stream water come from?
   - b. What is ground water?
2. To initiate activity:
   - a. How can one demonstrate ground water as the possible source of water in streams?
   - b. How does one collect ground water?
   - c. What is contained in ground water?
3. To continue activity:
   - a. How does the ground water differ at various points along a stream?
   - b. How does the terrain affect the ground water?
   - c. What other factors might affect the ground water?
4. To evaluate the student's performance:
   - a. Does the student understand the relation between ground water and stream water?

b. Does the student relate man's activities to a possible role in the pollution of ground water?

c. Has the student demonstrated the source of water in the stream picked for study.

III Equipment

1. Core sampler
2. Sledge Hammer
3. Shovel
4. Thermometer
5. Siphon or ladle
6. Sample bottles
7. Meter stick
8. Filtering equipment
9. Dissolved solids water chemistry testing kit.

IV Procedure

1. Have the students excavate test holes in the land beside a stream. These can be placed at varying distances away from the stream.
2. Have the students measure the depth to which water fills these holes.
3. Have the students take samples of the water from various test holes.
4. Have the students test the composition of the water from their test holes. Hint: to use colorimetric testing procedures filtering or centrifuging of the samples may be

necessary.

5. Have the students compare the composition of the water from their test holes with a sample taken from the stream itself.

V Past Studies

1. Students often have found that by placing their test holes to far from the stream they were unable to obtain any water samples. A graphic illustration of the concept of a water table was thus evident.
2. In some situations students were able to see that the water depth in their test holes was very close to equal to that of the stream.
3. Comparable water quality composition from the test holes and stream is often found indicating a common source. Students have extrapolated that the water in the stream is most probably from the water table they isolated in their test holes.

VI Limitations

1. Teachers may have trouble finding a stream convenient for this study. However, any small stream will do. Those without steep banks are particularly useful as the students will have a large area of lowland in which to excavate their holes with a probability of obtaining water in them.
2. Filtering and centrifuging the water samples is often nec-

essary as the suspended solids content of the samples is often high. This can be done with standard equipment.

3. Students should not be discouraged if there is not immediate filling of their test holes. The holes may not be deep enough!
4. Core samplers have a habit of clogging. Patience required.

VII Bibliograph

Ward, R. C. Principles of Hydrology, New York: McGraw Hill Publishing Co., 1967. Stimulating ideas and explanations of ground water and stream source is found in this somewhat advanced but easily readable reference.

L. Precipitation: measurement and evaluation

I Introduction

This activity introduces the student to precipitation in the hydrologic cycle as the input of water and input vehicle of nutrients to a study area. It is a possible study for all grade levels and is capable of being performed anywhere where it rains.

II Questions

1. To lead into the activity:
    a. What is rain and how does it form?
    b. What does it contain or is it pure?
2. To initiate activity:
    a. How can we collect and measure the amount of precipitation that falls on a particular area?
    b. What is the water quality of the precipitation?
3. To continue activity:
    a. What role does the chemical and nutrient composition of precipitation play in the system?
    b. By what means does precipitation pick up dissolved chemicals?
    c. Does the composition of snowfall resemble the composition of rain?
    d. What other means of nutrient input to study areas are there?

4. To evaluate the student's performance:
    a. Did the student devise a means of collecting precipitation so that he could accurately determine the amount and quality of the sample he obtained?
    b. Did the student understand the role of the nutrient input of precipitation as far as the system and its ecology is concerned?
    c. Did the student demonstrate the presence of dissolved solids in precipitation?

III Equipment

1. Basic Level
    a. funnels
    b. collection bottles
    c. evaporating dishes
    d. bunsen burner
    e. large, flat porcelain dishes up to one inch deep
    f. rulers
2. Advanced Level
    a. demineralizing water wash bottles
    b. chemical testing kit for water quality determination

IV Procedures

1. Basic Level
    a. Have the student collect precipitation in porcelain pans

   b. Have the student calculate how much has fallen in inches.
   c. Have the student evaporate to dryness some of the collection and observe the residual solid content
2. Advanced Level
   a. Have the student rinse all apparatus with distilled and then demineralizing water.
   b. Have the student collect precipitation as above.
   c. Have the student quantitatively analyze the nutrient content of his collection.

V Past Studies

1. Students have been able to compare the composition of precipitation from open areas, under trees, near factories etc. and through discussion have been able to realize the effects of these physical and biological characteristic on the system.
2. Students have often been able to gain an appreciation of the nitrogen cycle by measuring nitrate input in precipitation.
3. Students have found nitrate, sulphate, chloride, flouride, pH and total dissolved solids particularly useful determinations in chemical testing.
4. Students often have shown interest in developing new methods of precipitation collection.

VI Limitations

1. There are few limitations in this study particularly since it is capable of being performed on two levels or more.
2. It can be completed almost anywhere.
3. Teachers should make sure that all apparatus in advanced study has been throughly rinsed and demineralized. After such a process it should not be touched as even the dissolved solid content of sweat may effect results.
4. The nutrient content of rain is often very low.
5. The precipitation should be transferred to collection bottles soon after its collection as evaporation from collection pans will concentrate nutrient composition abnormally.

VII Bibliography

Borman, F.H. and Likens, G.E., "Nutrient Cycling," Science, 155: 424-429. A scientific but easily readable treatment of the role of precipitation in nutrient cycling.

Fisher, D.W. et al, "Atmospheric Contributions to Water Quality of Streams in Hubbard Brook Experimental Forest, New Hampshire," Water Resources Research, 4: 1115-1126.

Ward, R.C., Principles of Hydrology, New York: McGraw Hill Book Co., 1967.

Likens, G.E., et al., "The calcium, magnesium, potassium and sodium budgets for a small forested ecosystem," Ecology 48: 772-785. Scientific, but stimulating review of precipitation collection procedures.

M. The water budget of a small watershed

I Introduction

The purpose of this activity is to introduce the student to the hydrologic and nutrient cycle budgets of a small watershed. It is an advanced level study and is best attempted by the student who has completed a number of the hydrologic cycle activities.

II Questions

1. To lead into activity:
   - a. If we outline any particular area of land, what are the mechanisms by which water enters that area?
   - b. What are the mechanisms by which it leaves the area?
   - c. What changes are seen in the form of water while it is in the area?
2. To initiate the activity:
   - a. On a particular area of land, what is the total yearly input of water?
   - b. What is the total yearly out put of water?
   - c. By what mechanisms does water enter and leave the area?
3. To continue the activity:
   - a. Within the particular area, what nutrients enter and leave using the hydrologic cycle as a vechicle?
   - b. What physical and biological characteristics of the system effect the amount of water and nutrients flowing

through it?

   c. Is it possible to calculate a nutrient and water budget for the area of study?

4. To evaluate the student's performance consider:
   a. Although it will be unusual to have calculated a balanced watershed budget, does the student display an understanding of such a budget?
   b. Did the student realize that the input mius the output equals the change in storage within the system?
   c. Were the techniques and references used by the student to calculate input and output reasonable and successful?
   d. Did he realize that a long term study is essential for an accurate claculation of a hydrologic or nutrient budget?
   e. Was he aware of the descrepiences involved in such an activity and did he attempt to explain them?

III Equipment

1. References of climatological and hydrological data for the area of study
2. Equipment for measurement and testing of precipitation, transpiration, evaporation, flow etc. which has been outlined in previous activities and which depends on the number of parameters the student choses to study within the particular area.

3. Topographic maps and long distance measuring devices

IV Procedures

1. Have the student delinate an area for study
2. Have the student calculate the area of his system
3. Have the student calculate the yearly precipitation input
4. Have the student identify and measure other system inputs
5. Have student identify and measure other system outputs
6. Using extrapolation techniques and his own and reference data if available have the student calculate the hydrologic budget for the area.
7. Have the student collect samples of water from various inputs (eg. precipitation) and outputs (eg. outflow).
8. Have students chemical analyze the water quality for nutrients
9. Using extrapolation techniques and his own and reference data if available have the student calculate the nutrient budget of the area.

V Past Studies

1. Students in one study were surprized to see that the sulphate input of their precipitation was nearly equal to the output in outflow but that most of the nitrate input of precipitation remained within the system.
2. Calculated budgets have often been "unbalanced" by as much 50%, but students have often been stimulated by the question of what happened to all the precipitation that fell or why is this stream still running in such a period of drought.

VI Limitations

1. The study will be much facilitated if the teacher encourages. students to delinate small natural watersheds as their as their area of study.
2. Teachers can but may have trouble locating a watershed which is both small enough for feasible study and which has a flowing stream in it.
3. This activity is most valuable as the culminating experience in an examination of hydrology. Students are able to put as many previously learned techniques and understanding to work as they can.
4. Teachers should not forget the importance of continuing data collection in a study of this type. If this can be arranged the activity becomes a continuing one and its value will be greatly enhanced. If this can not be arranged an understanding of the concepts involved is very possible, but the quality of the budget calculated will inherently be low.

VII Bibliography

1. Borman, F.H. and Likens, G.E., "Nutrient Cycling," Science 155: 424-429. This is a scientific but readable account of the concepts and work which has been done in this area at Hubbard Brook Experiment Forest in New Hampshire. The study is a continuous one and the motivated student will find further references to it in its bibliography and in more recent publications.
2. Ward, R.C. Principles of Hydrology, New York: McGraw Hill Book Co., 1967.

Any human activity involving water affects the hydrologic cycle. Therefore it is important to see how man's activities do cause changes and it is important to evaluate these changes. In many cases there is a pressing need to reverse damage now being done and to correct the errors of the past. These activities show how the individual, the family, and the community affect our water resources.

Today, individuals consume and discharge water in greater quantities than ever before. However, today most people obtain a quality of water that is offered to them by a central supplier in the community. In a similar manner their waste water is discharged into a community service system. In effect, the individual may control his supply and disposal of water only in an indirect manner. He may not wish to pollute the nearby lakes and streams but if his sewage is processed centrally he cannot prevent the community from polluting unless he can exert enough political or economic force to redirect the efforts of his community.

Industry has developed in the United States as an extention of the concepts which operated during the great westward movement. Pioneering and carving out an existence by overcoming and utilizing the environment are second nature to many Americans. The concept that America's resources are limitless and require no management is typified by the inaction of industry and local government to voluntarily correct present pollution practices.

If this attitude is to be corrected, they must realize that any decision which affects the natural environment, affects an essentially fixed resource. All of us must now accept the principle that we must pay for what we use, whether we use up this fixed water resource in our recreation, our sewage disposal, industrial production, or our consumption of electricity. That we use our environment is necessary and acceptable. However, the future must differ from the past in that we can no longer only take from our environment but must perpetually renew and re-use what we take rather than the old pattern of using and discarding.

The activities in this chapter are classified under three major areas of inquiry: social configurations, economic endeavors, and recreational pursuits. The economic endeavors of man are considered on several levels according to the magnitude of the enterprise. We made the following distinctions: proprietorships, small industry, specialized industry, and conglomerates. A series of activities are also included which show the relationships between these areas of human activity and also relate them to other chapters in the guide.

The following general questions may serve to focus on the scope of inquiry in this chapter. Let "X" equal the particular human activity under investigation.

1. What is the influence of "X" on the nitrogen cycle in your area?
2. What is the influence of "X" on the hydrologic cycle in your area?

3. How do the economic factors of "X" influence its impact on environmental quality?
4. What is the general public's attitude towards the impact "X" has on the environment?
5. What is the legal situation pertaining to "X"? Are the laws sufficient to preserve the environment? Are the enforcement procedures adequate?
6. What are the roadblocks to lessening "X's" impact on the environment?

The following resources will be found useful throughout the entire section. Resources of particular interest are listed at the close of each activity.

Water Quality Criteria, McKee and Wolf, 2nd edition, State Water Quality Control Board, Sacramento, Calif., 1963.

Ecology, Life Series

Plants, Man and the Ecosystem, W.D. Billings, Wadsworth Pub. Co., Belmont, Calif., 1970.

Human Activities
A. Farming and Water Quality Draft

I Introduction

The purpose of this investigation is to involve students in a study of how farming in general and a given farm in particular, affect water quality. In this case we are looking at the effects of agriculture on the water cycle.

Any secondary student who has knowledge of the Nitrogen cycle should be able to succeed in at least the introductory level of this activity.

The activity would take at least 3 hours to complete, and could be spread over a short field trip and several class sessions. The more advanced activities would take a much longer period of time to complete.

II Questions

1. To lead the activity, ask students:
   a. What the nitrate level is in the wells and surface waters on the farm?
2. To initiate the activity, ask students:
   a. How are these data going to be obtained?
   b. What sampling techniques are going to be used; and what the effects of high nitrite are?
3. To continue the activity, ask students:
   a. What are the factors in farming practices that might lead to nitrogen in farm water?
4. To evaluate the students performance ask?

a. What were the nitrate levels on various areas of the farm?

b. What factors caused these nitrate levels?

c. What are the effects of agriculture on the nitrogen cycle?

d. Can we "afford" to have these effects?

III Equipment

1. Introductory Level

   a. Hach or Delta Kit to determine dissolved solids (can do nitrate or nitrite).

   b. Sample bottles.

2. Advanced Level

   a. Hach or Delta Kit

   b. Pipettes, burets (titration equipment to do analytical techniques).

   c. Millipore apparatus to do coliform and fecal coliform counts.

   d. Plankton net and collection bottles.

   e. Soil test kit.

IV Procedures

The questions listed above are designed to stimulate students to perform the following activities, among others.

1. Introductory Level

   a. Use Hach or Delta kit to determine nitrate and nitrite levels in well water, drinking water (if different) and any surface water (ponds or streams) that are on or near farm property.

b. Find out by asking the farmer, what kind of fertilizer and generally how much put on land.

c. Find out if there are any feedlots, or other collections of animal waste, and if so, how large they are, etc.

d. Determine amounts of Nitrogen that are in the soil.

e. What is the relationship between Nitrogen content of the soil and nitrogen content of water?

2. Advanced Level

   a. Determine the nitrite, nitrate, and ammonia levels in wells and surface waters near farm diurnally and seasonally.

   b. Determine variation of flow rate of streams, etc.

   c. Determine bacteriological content of above mentioned waters, and how they vary.

   d. Determine algal content of surface waters near or on farm.

   e. What is the affect of various crops on the nitrogen cycle?

   f. Does the kind of livestock being raised on the land effect the nitrogen level of the soil and water shed?

   g. Is there a difference in nitrate level between the run-off water and the soil?

h. Is there any correlation between fertilizer practice and nitrogen content?

i. Does it matter when the fertilizer is applied?

j. Is there any correlation between high bacteria counts and algae content?

k Where is the runoff from the feedlot (or Manure pile) going? What affect does this have on water quality? On the nitrogen cycle?

l. Be able to ask and answer more sophisticated questions.

V Past Studies (An example of a study)

A study was performed on the Swain, Connely, and Hershey farm in June of 1970. The study was performed to determine the effect of agriculture on the nitrogen cycle. The amounts and kinds of fertilizer added to the farms are listed in Table I.

Table I

Farm	Kind of Fertilizer	* Amount Added	Crop
Swain	Manure & 10-20-10	600 lbs./acre	Corn
Hershey	Manure & 15-10-10	600 lbs./acre	Corn
Connely	Manure & 15-10-10	600 lbs./acre	Corn

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* The amount of fertilizer added was the commercial fertilizer added. It was impossible to determine the manure added. Mr. Swain estimated the amount of manure add-

ed was 20 tons/acre/year.

The Swain farm had no surface or well water. All of their water was piped in from Tilton.

The Hershey and Connely farms obtained their water from wells. Table II shows the results of tests run on the water and soil from these two farms.

Table II Hershey-Connely Farm

	Nitrate	Nitrite	Nitrogen
Surface water	22 ppm.	.016 PPm.	
Well water	26.4 ppm.	0 ppm.	
Soil			*2% Def

* 2% deficiency would indicate a high nitrogen content.

It was extremely difficult to determine the effect of agriculture on the nitrogen cycles in the cites used.

Reasons:

1. Commercial fertilizers had been used for such a short period of time.
2. The total area fertilized was relatively small.

The amount of nitrogen in the soil and water that was tested was relatively high.

Some problems exist in doing a study of this type on a farm with a small operation. The amounts of fertilizers being put down are so relatively small, the effect on the environment would in turn be very small.

If this same study were performed on a farm that fertilized hundreds of acres or had 1000's of head of cattle, I'm sure that a greater effect on the environment could be ascertained. If the study were performed on a farm that had been using inorganic fertilizers for a long period of time the results would be different.

VI Limitations

A friendly and cooperative farmer has to be located. Sometimes it may be difficult for an entire class to invade a farm, one can probably send the class in shifts. Clothing should be rugged and the kind that cna get dirty --one of the advantages in this kind of study is that the students are "messing" around. Parents should be aware that this is going to happen, however, so that they can clothe their children accordingly.

The size of the farm will effect the kind of study undertaken. A small farm would not have the variations of practices to answer some of the questions asked. In many cases the farms of a given water shed or area would be practicing similar farming techniques so a total picture could not be undertaken.

If a choice is available, a farm that is large enough to have a) Different kinds of livestock, b) Different kinds of crops (corn, clover, hay, etc.) and c) A water supply that drains the areas studied.

VII Bibliography

1. Parameters for Detecting Pollutants With Respect To Farming
   - a. A.P.H.A. Standard Methods Gives Reagents, procedures for all nitrogen compounts, phosphates, ammonia compounds coliform bacteria, etc.
   - b. McGee, Wolf Water Quality Criteria Supplies interpretations on an elementary but complete level.
2. The Hydrologic Cycle, and How It May Be Affected By Farming
   - a. U.S. Dept. of Agriculture. Water, The Yearbook of Agriculture ($2.00, Superintendent of Documents, Washington, D.C.)
   - b. Bruce, J.P., and R.H. Clark. Introduction To Hydrometeorology , Pergamen Press, N.Y.
   - c. Ward, R. C. Principles of Hydrology McGraw-Hill.
3. Advance Readings
   - a. Journal, Water Pollution Control Federation (3900 Wisconsin Ave., Washington. D.C.

     Sept. 1969 Poultry Wastes-Nemerew

     Nov. 1969 Algal Growths-Azad et al

     May 1870 Phospherus Removal-Ames et al

B Community Survey

I Introduction

This activity is intended to arouse the students' interest in the effects of human activities on a body of water. This is done by locating sites which might be sources of pollution; collecting samples for the necessary tests; running the tests; gathering the data; and making tentative conclusions. Then, by contacting persons associated with the community, help them to understand what their water problems are. Any level high school student can complete this activity.

II Questions

1. Lead to the activity by asking:
    a. What are the possible sources of pollution on a body of water?
    b. What is the effect of a town's sewage and other effluents on adjacent bodies of water?
2. Initiate the activity with:
    a. What are the sources of sewage and other effluents and specifically where are they located?
    b. What types of tests should be utilized?
    c. What sites are to be used in the testing process? Are they representative?
3. Continue the activity with:
    a. Do we have enough data to reach a conclusion?
    b. How will we use our data to arouse public interest?
    c. Should letters be sent, people interviewed, information be handed out, etc.?
4. Evaluate the activity by considering:

a. Did the students understand the testing procedure and purpose?

b. Did the students eliminate variables that could produce errors in the data?

c. Are the students aware of the implications brought about by improper sewage and other effluent disposal practices?

d. Are the students cognizant of possible approaches that can be used to initiate public concern?

III Equipment

1. Sterile bacteria bottles (as many as needed)
2. Sterile Millipore System (media, Petri dishes, etc.)
3. Sterile bottles for making dilutions
4. D.O. bottles for D.O., I.D.O.D., and B.O.D.
5. Thermometer
6. Tape recorder to record conversations of interested people

IV Procedure

1. Field work

a. Sites which could show the possible source of pollution should be chosen.

b. Bacteria samples are collected.

c. D.O. samples are collected and fixed immediately.

d. I.D.O.D. samples are collected and fixed in 15 minutes. This will give an indication of the immediate dissolved oxygen demand that the micro-organisms exert on the D.O. content of the water.

e. B.O.D. samples are taken and placed in darkness for five days. At that time they should be fixed and titrated. This will show the total biochemical oxygen demand of everything alive or not living, in the sample.

2. Lab work

a. Prepare all materials for bacteriology in advance.

b. Find the amount of both fecal and coliform bacteria using the standard Millipore method. Fecal is done as well as total coliform because it is an indicator of sewage in the water.

c. Using the Winkler method, finish the D.O. and the I.D.O.D. tests. Then, five days later, do the B.O.D. test.

d. When all the tests have been completed, gather the data and tabulate it.

V Previous Studies

1. A group of students studied 6 sites near Wolfeboro, N.H.. Tests for total and coliform bacteria, D.O., I.D.O.D., and B.O.D. were performed. The effects of the effluents on adjacent waters was studied. Data from the above studies was presented to a newsman and the influential persons in the community. The article written by the newsman for the Granite State News appears below:

Water Samples in Wolfeboro Prove
Town is Polluting its Waterways

"Last Friday one group, and again on Monday a second group from the Tilton School Pollution Program were in the Wolfeboro Area taking water samples. The two groups, participants in the nationwide program centered at the school and financed by grants from the Ford Foundation and the Department of the Interior, were primarily interested in the general effect of human activities on a body of water. They were attracted to the Wolfeboro area by the abnormally high bacteria count in Wolfeboro Bay. In addition to this concern with water pollution, the program has two additional purposes. By forcing students and teachers into a close relationship outside the classroom, it is hoped that the program will serve a teacher training function. And, the program is also to prepare a learning guide based on the activities of the groups for use in studying pollution.

"In investigating the effects of human activity on the water supply, the groups took samples at five sites selected by Albert Powers, Head of the Science Department at Brewster. The first site was on Smith River above Wolfeboro Products, up stream from where Wolfeboro might have an effect on the water supply. The second site was by the dam at the excelsior mill in Wolfeboro Falls, the third by the sewer outlet in Back Bay, the fourth by the straw oil catch where the water from behind the shopping center flows under the railroad tracks into Back Bay, the fifth, under the bridge in the center of Wolfeboro. The sites were chosen so as to reveal any change in the condition of the water as it passed through Wolfeboro and to identify where these changes took place.

SITES TESTED

"At each site, tests were made to measure the oxygen dissolved in the water and also to measure the presence of bacteria in the water. Each group performed these tests at the sites with the Monday group acting as a check on the Friday group. The dissolved oxygen test measures the amount of oxygen in the water at the time of the test. From this, it is possible to determine what forms of life the water will support. Trout, for example, need a high amount of dissolved oxygen in order to survive.

"A second test, the immediate dissolved oxygen demand, measures how much of the oxygen is being used. If the amount being used is equal to the amount in the water then problems result because there is none left either for fish or organic breakdown.

"A third test performed measures the biochemical oxygen demand or, in other words, the amount of oxygen required by everything in the water. The absence of dissolved oxygen in addition to limiting the forms of plant and animal life also gives rise to hydrogen sulfide and methane gases. A super-saturated dissolved oxygen reading in which there is more oxygen in the water than can normally be dissolved at that specific temperature is also harmful. It appears to give rise to a higher disease rate and gill damage among fish. The tests revealed a super-saturated condition at sites two, three, and possibly four.

BACTERIA MEASURED

"Total coliform and fecal coliform counts were made to measure the bacteria present. The former indicates organic pollution such as sewage and garbage. The fecal coliform specifically measures the presence of organic matter from the intestinal tract of men and animals. Basing their conclusions on the test results and on the Recommended Use Classifications and Water Quality Standards of the New Hampshire Water Supply and Pollution Control Commission, they found that only site one was acceptable for bathing. The remaining sites would be placed in either class C or D due to the high bacteria count. Class C is "acceptable for recreational boating, fishing, and industrial water supply" while Class D is described as "aethetically Acceptable" and "suitable for certain industrial purposes". Evidence of recent fecal pollution was found at all sites except number one. And, a significant increase in the coliform count was found between sites one and two. This would lower the quality of water from class B to class C. The groups found oil and grease along with other floating solids at all sites except one. Using the Commissions" standards, the remaining sites would all be classified in class C using this criteria.

"While the two groups were quick to point out that the test results were only obtained from two sets of data performed by non-professionals, the similarities in the two sets of data did suggest the definite presence of a serious pollution problem. The results also gave a clear-cut, qualitative proof of the effects of human activities on a body of water. The groups noted that the state empowers local governments to set up laws regarding pollution where state laws do not apply and that any local board of health or any ten or more citizens could petition the water supply and pollution control commission if a public water is being contaminated."

by Roger Murray

VI Limitations

1. Before starting be sure that all health and safety precautions are taken.
2. Before undertaking field work, obtain permission to tresspass on any private properties involved.
3. A boat or float should be used in any study involving obviously polluted waters.
4. Prepared Petri dishes must be kept cool until the time of inoculation to prevent the growth of any bacteria which might have been introduced.
5. The sample must be inoculated soon after the time of collection to prevent the growth of coliforms which might have been introduced.
6. Rigorous precautions must be taken to insure the growth of only those coliforms originating within the sample.
7. Two samples should be taken from each site as a check on the validity of the results.
8. When counting colonies, respect the potential diseases within the Petri dishes.
9. One method for testing the dissolved oxygen should be selected and carried throughout the entire study to insure

uniform results.

10. It should be kept in mind that the Hach kit will not measure fractional parts of dissolved oxygen.
11. When on field studies testing for I.D.O.D. and B.O.D., a dark cool place should be readily accessible.
12. If there is a considerable distance between the site and equipment, chemicals to set the dissolved oxygen should be brought along to prevent aeration. (I.E. a steep decline of ten feet.)

VII BIBLIOGRAPHY

1. PARAMETERS of POLLUTION, WITH RESPECT to HUMAN INFLUENCE

a. Renn, Chas. :"A Study of Water Quality" La Motte Chemical Co. An elementary study of water, and how it can be altered by unnatural (i.e. "human activities") conditions.

b. Pelczar Reid:"Microbiology" pp.504-512, and also 500-504 give an excellent description of the coliform group of bacteria as indicators of possible fecal contamination. Page 513 gives a list of the effects of sewage on environment.

c. A.P.H.A. "Standard Methods, etc." Complete list of reagents preocedures, and some standards for all tests used.

d. Wells: "Design Specification Guide" Goodwin Hydrodynamics inc. An elementary discussion of B.O.D.

e. Needham and Needham: "A Guide to the Study of Fresh Water Biology". An excellent Algal and Macro-Invertebrate Key.

f. McKee and Wolf: "Water Quality Criteria" Complete interpretation of all tests performed.

2. ADVANCED READINGS ON THE LONG RANGE EFFECTS OF SEWAGE ON AQUATIC LIFE, and it's EFFECTS on ENVIRONMENT

a. Journal, WATER POLLUTION CONTROL FEDERATION 3900 Wisconsin Ave., Washington, D.C. 20016

(1) April, 1968: "Chlorination" - Thomas, Brown
"Activated Sludge" - Burkhoag, McKinney

(2) August, 1969 (part 1) "Phosphate removal" - Alburtsen, Sherwood
"Idonized sedimentation theory" - Hanson et. al
"Submerged effluent Collections" - Lutge
"Handly Gas Chlorine" - Connore and Fetch

(3) (part 2) "Bacteriology in activated sludge" - Lighthertt Oglesly
"Sludge Dewatering" - Nebiker et. al
"Denthal oxygen Uptake" - McBorinell, Hall

(4) November, 1969 (part 1) "Phosphorus Removal" - Barth
(part 2) "Al gal Growth" - Azad

(5) February, 1970 (part 2) "Viruses in waste water" - Moore
"Sludge Conditioning" - Tonnoy

"Stream Pollution" - Hoover et. al
"Ammonia Removal" - Mercer et. al
(6) April, 1970 "Tertiary Treatment" - Tchebanoglous

ALL are very detailed complete, biochemical studies. Very specific, very informative. The texts are for the average student, and are advnaced for someone not science oriented.

b. "Chemistry for Sanitary Engineers"; McGraw Hill
Very complete, advanced applications for chemistry

C. Drinking Water

I Introduction

This activity is primarily for urban schools where field work is sometimes difficult. This activity can be done completely in the classroom and the time varies between three and ten class days depending on the depth of study desired. This is suitable for students on the Junior or Senior High School level.

This activity gives the students an appreciation of their drinking water supply. This is to be done by having them discover the source of their water and how it is treated to make it pure. In the end they should realize that the water they pollute is going to be used by another community like theirs, who will have to clean it even as they are cleaning the polluted water they drink.

II Questions

1. To lead to activity ask: Where does our drinking water come from?
2. To initiate the activity ask:
   - a. How can we find out where the water comes from?
   - b. Is there a difference between the water we drink and the water at the source?
   - c. How can the difference be accounted for?
3. To continue the activity ask:

a. How is the water made fit to drink?

b. Is There a differnece between distilled water and tap water?

c. Is tap water the same all over the city?

d. How could a difference be accounted for?

e. What is the cost of cleaning the water?

4. To evaluate the student's performance ask:

a. How is our water purified?

b. Why is it cheaper and better to not pollute the source of our drinking water?

c. Why must some cities' water supplies be so far from the city?

d. How do you think your water system can be improved? Why hasn't it been improved?

e. How do large rainfalls effect your system? Drought?

f. How does pollution in your water supply effect you physically and economically.

III Equipment

1. Introductory Level

a. Untreated samples of water from the city's drinking source.

b. Maps showing the City's intake water system.

c. Books and movies on water purification if it is not possible to visit a plant.

d. Evaporating dishes.

e. Hach or Delta kit if available.

2. Advanced Level
   - a. Same as above plus:
   - b. Millipore equipment.
   - c. Material for building a rudimentary model purification system.

IV Procedure

The questions written above are designed to stimulate students to perform the following activities.

1. Introductory Level:
   - a. Trace the city's intake pipe to its source. Discuss the importance of the location. Find out if there are any industries by the source or if it is being used as a sewage dumping ground.
   - b. Compare sources from the tap and from the source (supplied by teacher). Have students note sensual differences between the two. Have them smell, feel and observe color differences. Do Not Have Them Taste Water.
   - c. Pour water samples into evaporating dish and let evaporate. Measure the difference in the amount of suspended solids.
   - d. Use Hach or Delta to determine chemical differenses. Suggested tests: pH, chlorine, fluoride, turbidity, iron, manganese.
   - e. Draw up summary of findings. This should generate discussion which leads into the next step.
   - f. Present information on how your water is purified.

g. Figure the cost per person of cleaning water.

2. Advanced Level

   a. Same as above but in greater detail especially for part (d).

   b. Run tests for bacteria. Refer to the bibliography.

   c. Visit a filtration purification plant if possible.

   d. Set up their own model purification plant.

   e. Have in speakers.

   f. Discover the economic soundness of cleaning polluted water for drinking versus clean water.

V Past Studies

To a certain extent some of the parts of this activity are traditional experiments. This activity was not performed in its entirety by the writers of this publication.

VI Limitations

Even with very little it should be possible to conduct this activity. The water from the supply can be picked up by students from different areas; several gallons will be needed. Maps free information and assistance can be gotten from the local water board.

VII Bibliography and Resources

1. Books:

a. Fair, Gordon Baskew; Water and Wastewater Engineering, 1966, John Wiley and Sons, Inc. New York. This book gives some general descriptions of water sys-

tems in towns and cities, but it is mostly a guide to the engineering of said systems.

b. Leopold, Luna B; A Primer on Water, 1966 U.S. Department of the Interior, Washington, D.C. pp. 37-30. This book gives a general description of how and why town and city water systems work.

c. Microbiological Analysis of Water, 1969, Millipore Corp. Bedford, (application report A.R *81)

d. Millipore Experiments in Microbiology, 1969 Millipore Corp. Bedford. The above two booklets describe methods of testing water quality and bacteriology counts. Millipore equipment is used.

e. Renn, Dr. Charles E.; A Study of Water Quality, 1968, LaMotte Chemical Co., Chestertown, Maryland. This is a brief booklet discussing water quality standards, water purification and waste water disposal.

2. Movies

a. Pure Water and Public Health, Cast Iron Pipe Research Assoc. This is a good description of the purification process. But use only as a last resort. It is largely selling cast iron pipes. Write to: 1168 Commonwealth Ave. Boston, Mass. 02134.

b. New Water For a Thirsty World, office of Chief Engineer, Bureau of Reclamation, Code 841, Building 67, Denver Fed. Ct. Denver, Col. A good description of the desalinisation process.

D. Pollution and Recovery

I Introduction

In this activity students will become interested in seeing the effects of a town or city on a given waterway. The fieldwork is uncomplicated, consisting of sampling the water above and below the community. The most striking results will be obtained by testing above and below a town or city, that has a substantial amount of industry with little, or not waste processing equipment. Two questions should be answered in this survey; what influence does industrial waste have on the over-all environment of a waterway? and; what is the recovery rate of a stream as the distance from the effluent is increased. A follow-up investigation whould be undertaken to study the influence of the time factor as it applies to recovery rate.

II Questions

1. Lead the activity by asking what effect industrial waste has on the over-all quality of this water system.
2. Initiate the activity by asking:
   a. Where should your water samples be taken in this stream?
   b. Why did you choose these locations? (This should lead to a discussion as to the desirability of collecting above, immediately below, and a considerable distance below the effluent.)
   c. Which chemical tests do you feel will prove most significant for this survey?

d. Which tests should be done on the site, and which may be brought back to the lab?

3. Continue the activity by asking:
   - a. Do you notice any prominant physical or biological changes in the immediate environment?
   - b. If we came back here tomorrow and collected samples do you think there would be a considerable varience in data?
   - c. What tests, other than chemical, would prove helpful in an over-all evaluation of this stream?
4. Questions such as these may help to evaluate the efforts of the students:
   - a. Did the investigation hold the interest of the majority of the students?
   - b. Did they seem eager to enlarge on the subject; as to which chemicals were doing the most damage to the system; where the most pollution was coming from; what action should come next?
   - c. Did all, or most, of the students enter eagerly into the task of testing the samples from the three sites?

III Equipment

Other than the laboratory testing kits very little is needed to carry out this investigation. The students should be encouraged to plan most of the procedures, and collect the needed field-work equipment: Sample equipment might include:

1. Collection bottles and fixing solutions for dissolved oxygen tests. (Winkler Method)
2. Collection bottles, any size, for general samples.
3. Collection bottles for bacteria; so labeled.
4. Testing kits and equipment, i.e. Hach, Delta, or LaMotte Kits. Ph testing kit, Pipettes and chemicals for Winkler tests for dissolved oxygen. D.O. meter (for comparison with Winkler test).

IV Procedure

1. Collect water samples from three locations on the river; above, immediately below, and a considerable distance below the industrial waste.
2. Take a meter reading, if possible, for dissolved O_2 at each location.
3. Fix the oxygen in one bottle from each location with solutions of manganese sulfate, and alkali-iodide-azide. (For Winkler test--dissolved oxygen.
4. Collect bacteria samples from each location.
5. Return to lab and make tests.

V Previous Studies

1. Previous studies of this investigation have pointed out to the students which dissolved solids are most closely allied with industrial waste.
2. Some students are surprised that a stream that shows a high degree of pollution just below an effluent shows a remarkab-

le degree of recovery over a comparatively short distance.

3. It has been noted that with most students there is a great desire to investigate the cause of each pollutant, and to work towards finding ways to eliminate the source. This investigation stimulates interest in over-all "ecolactics".

VI Limitations

Other than the bacteria cultures, which are demanding, very few factors can hinder significant results, from this investigation. Extreme accuracy is not important, as the comparison between above and below samples is very conclusive. Transportaion to collection sites is the only real concern. Suitable clothing should be worn. Hands should be thoroughly cleaned after collecting heavily polluted water.

VII Bibliography

1. Makenthum, K.M., The Practice of Water Pollution Biology, Dept. of Interior, Washington D.C., 1969. May be of some use for sampling techniques. Has little to offer over the testing kits.

2. Klein, L., River Pollution 3 Control, Butterworth & Co., London, England,1966. Very complete coverage of total river pollution problem. Advanced.

3. Ruttner, F., Fundamentals of Limnology, Univ. of Toronto Press, Toronto, Canada, 1969, pp. 56-104 Covers all dissolved solids found in fresh water. Quite involved for the beginning student.

4. U.S. Dept. of Interior, Pollution Control Administration, Biological Field Investigation Data For Water Pollution Surveys, U.S. Dept. of Interior, Supt. Of Documents, U.S. Printing Office, Washington, D.C. (Cost - 70¢). A very fine booklet for general use on water pollution; has a very complete list of ecologic terminology, and good chemical tables; especially on dilutions.
5. McKee, J.E. and Wolf, H.W., Water Quality Criteria U.S. Health Service, Dept. of H.E.W., State Water Quality Control Board, Sacramento, California, 95814. A very complete compilation of standards for all industry and household use of water. Standards for most stages are listed according to water usage.

E. Destructive effects of Water Pollution.

I. Introduction:

The activity, which has a field and lab procedure, shows the effects of water pollution on concrete or any other materials. Eighth grade students and above can relate certain human activities, causing water pollution, to the deterioration of materials stationed in the water. If a situation cannot be found where pollution is causing deterioration, this may be simulated in the lab.

II. Questions:

1. To lead to the activity determine if there is a body of water in your area affected by human activities. Then inquire:
   - a. Does the water have any effect on materials that it comes in contact with?
   - b. What are some of the human activities in the area that would cause pollution?
2. Initiate the activity by asking:
   - a. How would you determine the cause of the problem?
   - b. How could you find results and interpret them?
3. Continue the activity with:
   - a. Can you fit the interpretations into legislative action?
   - b. How can you set up a controlled laboratory experiment to simulate the problem? (Bioassay)

4. Evaluate the activity by determining:
    a. Did the students use a systematic approach to find and solve the problem?
    b. Did the student attempt to make any conclusions from the tests run?
    c. Can the student verify his observations?

III Equipment

The equipment required depends on the size of the body of water and whether it is a lake, stream, or river.

1. Dissolve solids testing equipment
2. Collecting 3 - 6 bottles of 1 liter capacity
3. Water gear (Boots, Boats, work clothes, bug spray)
4. Photographic equipment (optional)
5. Flow equipment (stop watch, orange, meter stick, 25 meter measuring tape)
6. Maps, data sheets

Lab Equipment

1. Bioassay materials
    a. Samples of materials (cement, wood aluminum boats, iron) steel
    b. Chemicals affecting materials (sulfurous acids, akalics, oils, synergism of chemicals)
    c. Distilled water

IV Field Procedure

If a stream and pollution problem is not available, use the lab procedure.

1. Find a material that is being affected by water problems.
2. Determine factors that cause material deterioration; a few of these are: natural erosion - corrosion, industrial wastes, algae. (see bibliography)
3. Collect equipment
4. Take water samples at representative sites.
5. Test samples to see if factors determined in procedure 2 are present.
6. If possible, interview human activities to gain knowledge of effluents added to the water Lab procedure.

or Lab Procedure

1. Determine factors that cause materials to deteriorate.
2. Set up controlled experiments to show how the factors affect the materials.
3. Draw conclusions.

V. Limitations

1. Field procedure requires affected area for study.
2. Much time and transportation is needed for testing and sampling.
3. Lab experiments could also take much time.

Note: The more concentrated the chemicals the quicker the results.

4. Testing knowledge of the dissolved solids.

VI. Past studies

Participants in a water Pollution study course at Tilton School, July 1970, made a study of the Daniel Webster Memorial Bridge in Franklin, New Hampshire, which was affected by cement corrosion. They also hoped to make an accurable report to the Franklin City officials. The corrosion could have been blamed on many factors. It could be natural; it may be caused by chemicals dumped from industries on the side of the river; it may be caused by dumping of snow (plus salt and sand) over the bridge, on to the cement foundation, during the winter. The tests consisted of D.O. Hydrogen Sulphide, Carbon Dioxide, Ph, Alkalinity, Sulphates, copper, nitrates, and phosphates. They were taken at areas that would show if any chemicals were added to the river; such as: above and below the entrance of possible effluents. After gathering results, interpretations were made. Research of chemicals that corrode concrete was made and compared to results. The chemicals and their effect are outlined below:

1. Corrosive factors that affect concrete
   a. Water mixed to make concrete should be suitable to drink (free from acids, alkalies, and oils.)

- b. Rate of flow of stream affects corrosion; density of cement is a factor in corrosion.
- c. Other factors of corrosions:
  - (1) Creosote, cresol, phenol, and many vegetable and animal oils.
  - (2) Sulfates
    - a. Sodium
    - b. Magnesium
  - (3) Sulfurous acids (SO_2) over 25 p.p.m.
  - (4) CO_2 greater than 20 p.p.m.
  - (5) Water with greater than 100 p.p.m. of carbonate hardness if water has low temperature and is constantly revewed.
  - (6) Sewage in waters of low ph and high temperature. Favors high H_2S which oxidizes into sulfates. Synergism between CO_2 and sulfates.

2. By-products of copper electrolite industry.
   - a. Copper smelting
   - b. Waste heat through cooling waters.
   - c. Waters with added sulfates and sulfuric acids.
3. Electroplating
   - a. Use of alkaline solutions and acids.
   - b. Use of demineralized water for rinsing.
4. Tanning
   - a. Needs low concentrations of free CO_2.

b. Needs low concentration of bicarbonate.

VII. Bibliography

1. McKee and Wolfe - Water Quality Criteria , State Water Quality Control Board, Sacramento, California Publication 3a-1963.

2. Chapter V, Quality Criteria for the Major Beneficial Uses of Water, Pages 88, and 96 discusses concrete corrosion. Also in the same chapter are explanations of industries that could dump effluents that are destructive. Pages 98 for Copper industry, Pg. 99, Electroplating and metal finishing; pg. 106 Tanning industry.

F. Sewage Treatment

I Introduction

In this activity students learn about sewage and waste treatment. The students learn how sewage is processed in their town and in neighboring communities. New laboratory techniques and equipment will be introduced which will enable students to determine the efficiency of various sewage treatment procedures and to appreciate, in a more precise way, the problems involved in an important but often neglected or unnoticed part of everyones life. The time required may vary from two to four periods or longer depending on the difficulty of selective procedure, student interest, and time and equipment available. The activity is designed for students from seventh grade and up.

II Questions

1. To lead the activity ask: What happens to the sewage and waste waters in your community after leaving their point of origin?
2. To initiate the activity ask:
   a. What type (Primary, Secondary, Tertiary) of waste treatment facilities does your community have, if any? (Consult local authorities, i.e. local health departments, sanitary engineers, et.)
   b. Are all types of wastes (sewage, run-off) treated in the

same way?

c. How effective is this treatment?

d. Could it be improved ? How?

3. To continue the activity ask:

   a. Are the methods of elimination of pollutants which you have encountered the most effective methods possible?

   b. If not, why not?

   c. What tests can be performed to determine the effectiveness of treatment plants?

4. To evaluate the students performance ask:

   a. Do you consider the sewage treatment in our community adequate?

   b. What can we as individuals or members of groups do to help improve sewage treatment methods?

III Equipment

The equipment and procedures which follow are listed in order of degree of difficulty. It can be beneficial for teacher and students to discuss what level should be undertaken.

1. Introductory Level

   a. Sample bottles

   b. Microscope

   c. Hach or Delta Kit

   d. Aquatic identification books for identifying micro-organisms.

2. Advanced Level
   - a. Same as above plus:
   - b. Millipore equipment or standard bacterialogical materials.
   - c. Titration equipment for Winkler, BOD.
   - d. Materials for constructing a model treatment system.

IV Procedures

1. Introductory Level

   The questions listed earlier are designed to stimulate students to perform some of the following activities.

   - a. Using microscopes and identification books identify the organisms found therein.
   - b. Using the Hach or Delta kit determine the level of nitrates in the water. Determine why this level is so important.
   - c. Draw diagrams of the local treatment plant.
   - d. Determine pH. Why is it important in processing sewage?

2. Advanced Level
   - a. Same as above
   - b. Using the Hach and Delta determine the level of dissolved solids you feel are important in sewage treatment based on what you have learned, in preparing for this activity and your study of the treatment plant
   - c. Using Millipore filter technique, or other methods, determine the level of bacteria before and after treatment.

Also determine why this level is important.

d. Determine how bacteria is used in sewage treatment. (Discussion)

e. Determine the level of DO, IDOD, BOD in water before and after treatment, and in the body of water into which the treated sewage is dumped. Discuss the significance of the results. (refer to Standard Methods for technique)

f. Build a model sewage treatment plant.

V Past Studies

(1) A group of students from Quincy, Mass. found their bay to be suffering from rapid biological aging (eutrophication). Also, it was being polluted by "storm" drains from a combination storm-sewage system. They studied the advantages and disadvantages of secondary treatment, the dangers of daily chlorination, and the problems of algae to dye humans (ie city council)

(2) Another group of students from Quincy, made a study of the effects of sludge being pumped into the bay at a rate of two million gallons a day. They concern themselves with B.O.D., eutrophication, and floating solids.

(3) Limitations

If there is no treatment plant in your area it will be necessary to take field trips. Movies and books may have to replace the primary learning and experience of visiting the plant. Supplemental equipment may consist of: paper chromatography, standard analytic procedures; quantitative and qualitative analysis, etc.

VI Bibliography

1. Introduction to Sewage Treatment:
    a. Pelczar, Michael, Reid: Microbiology, McGraw Hill. An excellent source for an outline of sewage treatment. pps. 511-522 discuss the biology and chemical characteristics of sewage, and outlines Primary and Secondary treatment.
    b. U.S. Dept. H.E.W. Municipal Sewage Treatment Process No. 002599. Good film for teacher and student to lead into and initiate activity; B and W, slightly outdated.
    c. Renn Chas, A Study of Water Quality LaMotte Chemicals Co.. An elementary discussion of water quality and how it can be altered by unnatural conditions. Good background materials; good references.
2. Parameters of Sewage:
    a. Pelczar: pp. 500-504, excellent discussion of the Coliform group as an indicator of pollution. Very complete, and the reading can be done by the "average" jr. high student. Page 513 gives a list of the effects of the sewage on environment.
    b. APHA: Standard Methods, etc.. A complete set of directions from making reagents to performing tests. A re-

quired reference. Quite complicated.

c. Environment Vol. 12, no. 2, March 1970. A new Prospect. A study of parameters of sewage, and problems of sewage on environment. A good study of the effects of sewage on environment. Wells Design Specifications Guide, Goodwin Hydrodynamics Inc., Weirs Beach, N.H.

3. Advanced Reading On the Long Range Efforts of Sewage and Discussions of Secondary and Tortiary Treatment.

a. Journal, Water Pollution Control Federation (subscription, etc., address: 3900 Wisconsin Ave., Washington, D.C. 20016)

(1) April, 1968 Chlorination, Thomas, Brown
Digestor Failures, Zablotsky, et.al
Activated Sludge, Durkhoag, McKinney

(2)August, 1969 Phosphate Removal, Alburtson, Sherwood
Idonized Sedimentation Theory, Hanson
Submerged Effluent Collections, Lutge
Landly Gas Chlorine, Connore and Fetch

(3)(part 2) Bacteriology in Activated Sludge,
Lighthrtt Oglesby
Sludge Dewatering, Nebiker et.al
Benthal Oxygen Uptake, McDerinell, Hall

(4) Nov. 1969 Phosphorus Removal, Barth
Algae Growth , Azad

(5) Feb. 1970 Viruses in Wastewater, Moore

Sludge Conditioning, Tenney

Stream Pollution, Hoover et.al

Ammonia Removal, Mercer et.al

(6) April, 1970 Tortiary Treatment, Tchobanoglous

All are very detailed, complete, Biochemical studies. Very specific, very informative. Not the average student, and very affluent for someone not science oriented.

Chemistry for Sanitary Engineers McGraw Hill. Very complete, advanced applications of chemistry.

G. Biochemical Oxygen Demand In Sewage

I Introduction

The B O D test, Biochemical Oxygen Demand, is designed to determine the amount of oxygen bacteria required to break down sewage. There are three factors in the breakdown of sewage which require oxygen, (a) carbonaceous organic material useable as a food by aerobic organisms, (b) oxidizable nitrogen and organic nitrogen compounds which serve as food for specific bacteria, (c) certain chemical reducing compounts which will react with molecularly disolved oxygen. There is an incubation period of 5 days in which the three factors above are given time to use oxygen. Therefore for one to incorporate this activity into the class room, one must make time for collection of samples, seeding and after incubation, the B O D test. The activity may be designed to fit almost any age group. It is a good activity with which to teach lab techniques for tenth graders and older students.

II Questions

1. To lead to the activity ask:
    a. What causes the breakdown of wastes?
    b. What must be present for this breakdown to occur?
    c. Would it be possible that there may not be enough of this substance to complete this breakdown of the waste?
2. To initiate the activity ask:
    a. How shall we test for this substance and find out if

3. To continue the activity tell the students the procedure for the B O D test and let them continue with testing of sites of their own choice. Because of the complexity of this procedure, the teacher must answer the students questions directly.
4. To evaluate the students actions observe who participates, how much work each individual does, and how well they do the work. Also watch the organization the students build up on their own.

III Equipment

1. 500 ml sample bottles
2. 300 ml sample bottles
3. Some standard method of determining D O
4. Pippets
5. Graduated cylinders
6. Beakers
7. Heavy brown paper
8. Tape and marking pencil

IV Procedure

The procedure given here is very sketchy. For more detail, refer to Standard Methods.

1. Prepare an organic-free dilution water. Distilled water may be used.
2. Determine the D O content of the dilution water.
3. Determine the D O content of the waste water to be tested.

4. Make several dilutions of the prepared sample so as to obtain the required depleations. The following dilutions are suggested. 0.1-1.0 percent for strong trade wastes, 1-5 percent for raw and settled sewage, 5-25 percent for oxidized effluents, and 25-100 percent for polluted river waters. The dilution of the samples is called seeding.
5. Put an air tight seal on the bottles and store in a dark place for 5 days at a temperature of 68 degrees F (20 degrees C).
6. During the incubation period, calculate the initial D O content of the incubated sample. Below is the equation for calculating the initial D) content of the incubated sample.

   $\frac{(x)}{(y)}$ (d) = p.p.m. D O contributed by waste water

   x is the amount of waste in the incubated sample

   y is the total content of the incubated sample

   d is the D O content of the waste water.

   $\frac{(z)}{(y)}$ (D) - $\frac{\text{ppm}}{\text{ppm}}$ D O contributed by dilution water
   D O Total D O initially

   z is the amount of dilution water used

   D is the D O content of the dilution water.
7. After 5 days, determine the D O content of the waste water-dilution water misture.
8. On the basis of oxygen depletion and the relative proportions of waste water and dilution water, calculate the oxygen demand of the organic material in the waste water. Use the

$$\frac{(y)}{(x)} (I - H) = \text{p.p.m. of oxygen demand or B O D}$$

I is the total D O Initially

H is the D O of the sample after incubation

V Limitations

The greatest limitations of the B O D test for classroom application, is the fact that the procedure runs into much technicality. However, with some modification, the test may be fitted to younger age groups. It would be wise to be well informed before proceeding. One must also have fairly reliable equipment in order to procure accurate data. At least a half a day should be alloted for completing the sample collecting, and preliminary testing before incubation.

VI Past Studies

1. A group of students concerned themselves with setting parameters of sewage influent-effluent flow, concentrating on the ability of secondary treatment ot remove oxygen-demanding materials from sludge.
2. A team of students attempted to isolate the three classes Standard Methods) of oxygen-demanding materials.

VII Bibliography

1. Introductory Literature
   a. Pelczar Reid: Microbiology, pp. 512, an excellent operational definition of B.O.D.
   b. Goodwin Hydrodynamics, Design Specification Guide. A

good elementary procedure for preparing and performing B. O. D.

2. Advanced Readings

A.P.H.A. Standard Methods, Complete information on seed dilution factors, etc. Not for the average student.

H. Effect on Oil on Aquatic Life in Recreational Waters

I Introduction

The Water Quality Act of 1965 states the following: "Standards of quality.....shall be such as to protect the public health or welfare, enhance the quality of water and serve the purpose of this act." Included among substances banned from recreational waters are floating debris, oil, scum and other matter. This study regards fuel oil discharged by small craft on recreational waters. Concentration higher than 50 gal. per square mile may coat the bodies of bathers causing skin irritation. This oil sometimes blocks sunlight, thus preventing photosynthesis in aquatic plants at the bottom of the body of water. It can also stick to the gills of fish and interfere with their respiration. It may also coat the bottom of the body of water, endangering spawning areas. Ninth graders and above may do this activity.

II Questions

1. To lead to the activity ask:
    a. How does oil on the surface of recreational waters affect aquatic life?
    b. How could a student test the effect of fuel oil on a certain type of aquatic life?
    c. In testing to find this effect, which would be more advisable to use; plants or animals?
    d. How would you collect the living specimens that you

would like to use?

   e. What do you think that you would need to perform this experiment?

2. To determine the quantitative relationship of oil concentration and the surfact color, ask:
   a. What is an oil slick?
   b. At what concentration of oil does the slick become visible?
   c. At what concentration is an oil slick seen as a silvery sheen on the surface of the water?
   d. At what concentration of oil are bright bands of color visible?
3. To evaluate this experiment ask:
   a. Why did you use a control during the experiment?
   b. Was timing accurate during this work?
   c. Were all of the organisms used during this project of the same species, size, et., and do you think that any variations, in these could have changed the effects of this experiment?

III Equipment

1. Net
2. Container in which to place organisms that are caught.
3. Tank in lab to keep organisms in water from natural habitat.
4. Beakers

5. Graduated cylinders
6. Pipettes
7. Watch with a good second hand.
8. Oil (inexpensive)

IV Procedure

In addition to field trips to observe oil on lakes and streams, complete the following to see the effect on fish.

1. Add 1 ml. water to beaker #1, 5 ml. to #2, 10 ml. to #3, 15 ml. to #4, and 15 ml. to #5 (control).
2. Add 3 ml. of fuel oil to each beaker except control.
3. Note time of addition of oil and time of death of fish.
4. Record data carefully.

V Previous Studies

1. Chipman and Galtsoff (1949) showed that low concentrations of oil are toxic to fresh water fish.
2. Pickering and Henderson (1956) made toxicity studies of oil on minnows.

VI Limitations

1. Be sure to have a small fish net because it is difficult to remove a small fish from the tank.
2. Make sure that the smallest amount of water (in this case, 1 ml.) is enough to support the size fish you are using.

VII Bibliography

1. FWPCA, Report of the Committee on Water Quality Criteria, April 1, 1968. We found references to previous stud-

ies made on this topic.

2. FWPCA, Water Quality Studies: Clean Water, Training Manual, U.S. Dept. of the Interior, October 1969. Good references on the affect of oil on the surface of water.
3. McKee, Jack E., and Wolf, Howard W., (ed.), Water Quality Criteria, State Water Quality Control Board (Cal.), 1963. This book contains good references to fuel oil.

I. The Effects of Damming or Impounding Water

I Introduction

This investigation was devised to determine the long range effects a dam has on river and the difference in the present day condition of the river above and below the dam. Eighth graders and older students with a background in the various water pollution tests may complete this activity.

II Questions

1. Lead to the activity by asking:
   a. What biotic and abiotic factors are involved in a stream's equilibrium?
   b. How would a dam interfere with these factors? Specifically, which factors would be altered?
2. Initiate the activity with:
   a. How would you measure the changes caused by the dam?
   b. What tests might be performed to measure such changes?
3. Continue the activity with:
   a. What are the interrelationships between abiotic and biotic factors?
   b. How would different dams affect different dams affect different purposes, for example, a recreation dam as opposed to one used for flood control. Would a dam used to generate electricity by hydroelectric powers produce problems different from those created by a steam generating plant located at the dam?

4. To evaluate the activity:
   a. How did the student solve problems which arose from the physical characteristics of the site (depth of stream to great to be measured without a raft, the problems of gaining access to a dam, etc.)?
   b. What have the students found to be the advantages and disadvantages of impounding water?
   c. Has the student gained an understanding of the term "watershed"? Can he outline the watershed of this river? Can he predict the effects of an unusual condition which might occur upstream?
   d. Can the student offer explanations for differences he noted up and down stream of the dam?
   e. Does the student feel he has gained an understanding of the problems involved in the planning and maintenance of such a body of water?

III Equipment

1. Hach kit, Delta-50 kit or LaMotte Kit
2. Dissolved oxygen meter
3. Secchi disk for measurement of turbidity
4. Meter stick
5. Rope or chain
6. Styrofoam ball or orange
7. Watch with second hand or stop watch
8. Thermometer

9. Life raft perhaps
10. Core sampler
11. Kemmerer sampler for collection of water at great depths.

IV Procedure

1. Selection of a site.

The site should be employed only after some investigation. One must determine whether or not access to the dam can be gained. The best way of locating a site may be to check the map, and then to be in touch with the personnel at the dam so that selection of siet will be made easy.

2. Short range vs. long range procedures.

Rather than simply performing the tests once one might perform them over a succession of days or months. In addition one might fine statistics from previous studies of the area and compare these to the data he has collected.

3. Actual testing.

Turbidity, dissolved oxygen and carbon dioxide, pH, and temperature may be determined above and below the dam. Tests for rate of flow might be performed. Additional studies of settling rates of suspended particles, the contents of a core sample, and various tests of deep water samples may be carried out.

4. Correlation

Comparison graphs of biotic and abiotic factors might be made. From this conclusions on the dam's effect on the abiotic factors and biotic factors may be made. It is no doubt wise to be in touch with the State Health Department for example, for it is from them that previous data may be obtained.

V Previous Studies

1. A group of students studied a dam and the river at sites above and below the dam. They were amazed at the affect of impounding the water, on the surrounding community.
2. Another group studied a flood-control dam which was also used for recreation. It was interesting to determine whether both could be done similtaneously and still effectively.
3. A group was interested in the trees of the area surrounding the dam and suggested further study.
4. Still another group, in its study, attempted to determine whether siltation occured and what its long-range affects might be.
5. In one study students discovered that the installation of a sewage treatment plant, several miles above the dam site produced startling results in the bacteria and dissolved oxygen counts. (Further investigations as an outgrowth of this, in the calss-room situation).

VI Limitations

1. Short-Range Study
   a. Access to the desired site can not be assured due to the abutments in the structure of a dam. Thus, the student

must bring a long rope with which to suspend a bucket, thermometer etc., to test the water. In such cases the Core and Kemmerer Samplers are helpful.

b. The Kemmere Sampler presents many problems. A chain must be used to suspend the sampler. One must make sure this chain is straight, in order that the messenger can slide freely down it. In hauling up or letting down the chain, the hands may be hurt by friction caused. To prevent this, a wench or rubber gloves should be brought along.

c. Below the dam, at your site, make sure the water is not so turbulent as to prevent access.

d. In getting flow, make sure your raft is far enough removed from the generators intake valves so that it is not effected by the under current. (i.e. sucked in)

e. Suggestion: If your dam is used for the production of electricity, take a tour of the plant if at all possible; its interseting.

2. Long-range Study

a. One note may be made here, and that is that water pollution surveys do not date back to before the 1940's in most cases. Because of this the dam the study is performed on must be relatively young.

b. Suggestion: If at all possible make a comparison between the bottom topography of the stream before and after the dam was built.

VII Bibliography

1. Field Biology and Ecology, Allen H. Benton, Wm. E. Werner Jr., McGraw Hill Book Co., New York.
2. Plants, Man and the Ecosystem, W.D. Billings, Wadsworth Publishing Co., Belmont, California 1970.
3. Basic Ecology, Ralph Buchsbaum, Boxwood Press, Pittsburg, Penna.
4. Concepts of Ecology, Edward J. Kormondy, Prentice Hall Biological Series, T.H. Inc. Englewood Cliffs, N.J.
5. Fundamentals of Ecology, Eugene P. Odum, W.B. Saunders Co., 2nd edition, Philadelphia, Penna.
6. Ecology, Life Series

J. Community Water Supplies

I Introduction

In this activity it is presumed that the student has an understanding of the amount of water needed or used by urban centers. From this point he will proceed to discover from where this water comes and what steps are taken to protect the water supply. Several other avenues are opened as possible future activities depending on the interest of the student. This activity may be carried out by sicth through twelfth graders.

II Questions

1. To lead to the activity ask, Where does your water caome from?
2. To initiate the activity ask What is the watershed of the water supply?
3. To continue the activity, ask:

   At this point several paths are opened which might be followed to advantage:

   a. What controls are made on the human activities within the watershed? What are the provisions of enforcement of these controls?

   b. If an impoundment exists, what have been the effects down stream of the dam?

   c. Has the evaporation of impounded water caused detrimental concentrations of dissolved solids? Are any impounded supplies faced with this problem?

d. Evaluate the effectiveness of the controls placed on the watershed by comparing the water run-off with that of an equal sixe region which is not controlled.

e. If supply is a flowing river what controls are placed upon the upstream facilities such as cities, industries, etc. What are state controls on effluents? If the river is an interstate one, how do state controls compare?

f. How does the seasonal variation in the river flow affect the concentration of contaminants?

g. If the supply is a deep well, try to trace the underground flow by reference to geologic factors. For instance, much of the deep water in midwestern plains states originates in the Rocky Mountains. How does this long path affect the water quality and flow available?

4. To evaluate the student's performance have him describe the water sources of his urban community and give the factors which he feels are important to its preservation.

III Procedure

1. Contact should be made with the public water supply department to obtain a map showing the water wupply or supplies of the urban center. The supplies may be surface entrapment, deep well, or flowing river.

2. If the supplies come from a deep well source a geologic map showing underground structures and sand-bearing strata would

be needed. If impounded, a topographic map would be needed and the region contributing water to the impoundment would be outlined. (This assumes a knowledge of map reading).

3. If the source is a flowing river, a topographic map of large area coverage would be required and the watershed outlined. The towns, cities, and industries in this watershed should be designated.

IV Equipment

1. Appropriate maps
2. Contacts with state and city departments responsible for public water supply.

V Past Studies

To date, no known past studies on a secondary level have included a thorough investigaion of the sources and methods of protection for a municipal water supply.

VI Bibliography

A Primer on Water, U.S. Department of the Interior, 1960, available through the U.S. Government Printing Office, Washington. A simplified pamphlet (good for 6th - 12th grade use) explaining hydrology and water use, including city water systems.

Water Quality Criteria, McKee and Wolf, 2nd edition, State Water Quality Control Board, Sacramento, Calif. 1963. Good reference on the major uses of water, including domestic water supply.

K Investigating Lead Concentrations in Automobile Exhausts.

I Introduction

In this activity lead concentrations of car exhausts will be investigated. This project is an outgrowth of water pollution investigations. It was a natural development which takes advantage of procedures common to water pollution work. One of the intentions of this activity was to make a springboard from which other types of lead concentration-investigations could be devised.

II Questions

1 Which lead to the activity

- a. Why are large amounts of lead in the air a problem?
- b. Where does most of this lead come from?
- c. What is lead used for in gasoline?

2 Which initiate the activity

- a. Would different types of cars give off differing amounts lead?
- b. Would the type of gasoline used determine in any way the amount of lead given off?
- c. What types of gasoline give off the most lead?

3 Which continue the activity

- a. How do the lead concentrations given off by automobiles compare with the amounts given off by other internal combustion powered machine, i.e. uses, trucks, motorcycles, lawnmowers, etc.?

4. Which evaluate the activity
   a. How do the data collected in this activity compare with other studies in this area?
   b. What interfering factors and built-in errors might there be in this method of testing?

III Equipment

This activity uses a hydrid hach-millipore procedure. Millipore air pollution equipment is used for detecting the lead and then the hach collorimeter is used to give quantitative results. Standard Millipore sir testing equipment including filters, number AAWG04700 and pads number HAWG04750.

Tetrahydroxy - p benziquinone

Isopropanol

Acetone

IV Procedure

1. Make up standard solutions of lead nitrate to be used to calibrate the metering system.
2. Draw solutions through filters, solubilize these in 25 ml. of Acetone and read on the colorimeter.
3. Make up indicator solution of tetrahydroxy quinone by dissolving an excess amount of tetrahydroxy - p - bengi-

quinone in 10 ml. of Isopranol, filter, and then through this filter pour 10 ml. of distilled water to produce the workable 20 ml. solution.

4. Place 2 ml. of this solution on a pad in a petri dish.
5. To collect sample place a filter in the sterifill system and place over the exhaust pipe a limiting orifice should be used in the connection to the vacuum source. The sample should be collected for a standard amount of time.
6. Place the filter on the THQ-soaked pad, face up, and allow 30 seconds for the purplish color to develop.
7. After 30 seconds place the filter in a colorimeter bottle containing 25 ml. of acetone and shake vigorously to dissolve the pad.
8. Read the sample in the colorimeter on scale number 2667 using filter number 2408. The colorimeter should be calibrated with colorimeter bottle of pure acetone.
9. Compare to standards to get milligrams of lead per liter of exhaust.

V Past Studies

The author developed this test from millipore's qualitiative procedure for determining the presence of lead. Lead nitrate solutions ranging from .01 to .1 grams of lead nitrate were made up. Because of a lack of time not e nough were made up to make as accurate a test as would be desired. Therefore it is hoped that participants will make their own scaling system. To do this, many standards were made up and pulled through filters and then measured in the standard way. The results were then graphed and a formula was devised to give a result. This formula is: -0.004 x meter reading + 0.339 = lead nitrate

However, this only gives the number of equivalant grams of lead nitrate in the whole sample. A workable number was desired. Therefore the number gotten by the formula was multiplied by .6 which is the amoung (by mass) of lead nitrate that is lead. In this study a 14 liters per minute limiting orifice was used and samples were taken for one minute. The answer from above, them, would be the number of grams (or milligrams) of lead in 14 liters of exhaust. The answer was then standardized to one liter by dividing by 14. To summarize, the method of obtaining a quantitative result was to use this formula: lead nitrate x .6/14 = mg. of lead per liter

The tetrahydroxy - p - benziquinone is quite expensive. It was found that very little was wasted if the filtrate was re-used. No noticeable loss in accuracy was observed.

The indicator solution was found to go bad quite quickly, sometimes in as little as a few hours. This is the reason for mixing in such small quantities. The color produced by the lead also fades quickly.

VI Limitations

The main limitation of this test is the questionable accuracy thereof. However more work in this area could aleviate this problem. Other limitations are: The expense of the chemicals and equipment, the expendiency with which the test must be done to preserve accuracy, and the safety factor which must be kept in mind while working near exhaust pipes.

VII Bibliography and Resources

Millipore booklet ADM - 70

Ecological Perspectives

To understand the effects of pollution, one should study organisms and determine their relationship to the non-living part of the environment in which they live. An ecological perspective results when these relationships are understood as they effect the quality of the abiotic environment.

Previous studies[1] indicate that a single group of organisms (with the exception of coliform bacteria) are not reliable as an indication of water quality. Only a total biotic study reveals the true quality of a body of water.

The activities presented in this section employ techniques of bacteriology, aquatic biology, chemistry, geology, physics, and engineering to delve into aquatic ecosystems. The following fundamental questions, dealing with a given aquatic system, outline the scope of this chapter.

1. How many kinds of organisms are present? What else is present?
2. What is the diversity index above and below an effluent on a given stream or around the shoreline of a given lake?
3. What is the relationship between any two of the following to the diversity index of a waterway:

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[1] Biological Field Investigative Data for Water Pollution Surveys, page 4, U.S. Department of the Interior, FWPCA.

suspended solids

flow

type of bottom

dissolved solids--phosphate, nitrate, sulfate, chloride, iron copper

dissolved gases--oxygen, carbon dioxide, methane, hydrogen sulphide

4. What is the effect of varying concentrations of a dissolved solid such as Cl or phosphate on the species population or diversity index of a microcosm?
5. Does the diversity index change as one goes downstream?
6. a) What are the species populations of an aquatic system?
   b) What is the biomass and/or energy flow in a particular system?
7. Do the concentrations of dissolved oxygen and carbon dioxide change over a 24 hour cycle? Does the diversity index of an aquatic system change over a 12 month period.

The following resources will be found useful throughout the chapter. Resources of particular interest are listed at the close of each activity.

Hedgepeth, J. W., Obtaining Ecological Data in the Sea, Chapter 4 in Treatise on Marine Ecology and Paleoecology, Memois 67, Geological Society of America, 1963.

A good reference for marine studies.

Memois 67, Geological Society of America, 1963.

A good reference for marine studies.

Pennak, R. W., Fresh-Water Invertebrates of the United States, Ronals Press, New York, 1953.

A good general reference. Very technical.

Needham, J.G. and Needham, P.R., A Guide to the Study of Fresh-Water Biology,

Holden-Day, Inc., San Francisco. (paper) 1962

Excellent drawings of organisms. Easily carried in the field.

Standard Methods for the Examination of Water and Wastewater, 13th ed., American Public Health Association, Inc., New York, 10019. 1971.

Discusses biological collection techniques, bioassays, and chemical analysis. Good drawings of organisms. Every school should have at least one copy.

Usinger, R.L., Aquatic Insects of California, University of California Press, Berkeley, 1956.

Can be used in most locations in the U.S.

Welch, P.S., Fimnological Methods, the Blakiston Company, Philadelphia, Pa., 1948.

Highly recommended.

Wilkm, J.L., Patterns of Numerical Abundance of Animal Populations, p. 147-150, The American Biology Teacher, March 1969.

A diversity index is presented as well as other means of statistically analyzing biological data.

A Aquatic System

I Introduction

The purpose of this investigation is to get students involved in studying a total aquatic system. This activity would be carried out to begin the study of Ecological Perspectives. Most of these activities would take place at the secondary level; however with proper teacher adaptation, some could be used at elementary levels. The basic and advanced levels differ mostly in the accuracy and therefore the expense of the equipment involved.

II Questions

1. To lead to the activity ask: How many kinds of plants, animals, and microbes are present in this aquatic system?
2. Initiate the activity by posing: How are you going to collect these?
3. Continue the activity with: What are the physical characteristics of the system?
4. Evaluate the performance of the students by considering questions such as:
    a. How many species were present in the student's samples?
    b. How many did the students find?
    c. Were the samples representative?
    d. What are the pertinent physical characteristics?
    e. Did the students study them?

f. How well did the students work? (As opposed to hacking)

g. What seemed to interest them most?

h. Were the students able to fit all the parts together and form an understanding of the whole system?

III Equipment

(The Equipment and Procedure sections are suggestions only. Teachers should encourage their students to develop equipment and procedures of their own.)

1. Basic Level
   - a. several thicknesses of cloth to filter out microbes
   - b. some screen to collect bottom dwelling organisms
   - c. container for collected plants
   - d. a float for estimating stream flow
   - e. a can for collecting bottom sediment or gravel
   - f. a microscope
2. Advanced Level
   - a. a plankton net or membrane filter apparatus
   - b. a Surber Sampler or Ekman Dredge--You can make your own quantitive samplers.
   - c. containers and keys for collected plants
   - d. a stream flow meter or a watch with a second hand, a meter stick, and a float
   - e. core sampler, Ekman Dredge, or Kemmerer Sampler

f. a microscope, counting cells such as Sedgwick-Rafter, or Palmer, or haemocytometer.

IV Procedure

1. Basic Level

a. Pour sample water through cloth and study residue by making wet mounts on microscope slides.

b. Place screen in rift, then:

(1) disturb bottom by moving stones,

(2) remove organisms from screen and place in container, and

(3) sort out species

c. Pick representative plants from various kinds present and place them in container

d. Estimate the time it takes for the float to go a given estimated distance, estimate width and depth, and calculate flow in cubic units per time

e. Get a bottom sample with a can, determine particle size with screen, and observe organic matter present.

2. Advanced Level

a. Run a known volume of water through the net or filter, then determine by microscope the number of kinds present per volume of water.

b. Collect bottom sample with Surber, Ekman, or improvised collector, then determine types present per unit area.

c. Collect representatives of all plant types using quadrat, if desired, then use keys to identify plants.

d. Calculate the flow useing flow meter or watch, meter stick, and float.

e. Get a bottom sample using core sampler, Kemmerer Sampler, or Ekman Dredge.

f. Determine particle size by using differential settling or by using a series of different meshed screens.

g. Do a microscopic study of particle size.

h. Determine the percent of organic matter by massing, fire treating, and remassing.

V Previous studies

1. Some sixth graders delighted in drawing what they saw in their microscopes. They placed their drawings on the bulletin board.
2. A third grade class was extremely interested in picking macroinvertebrates from a bottom sample.
3. Second year biology students reacted strongly to the lack of diversity in a polluted bottom sample. They had thought that pollution just happened to the water.
4. A group of freshmen students thought that their flow data were wrong because flow decreased as they went down-

stream. They investigated further and found out that a water supply company was taking water from the stream.

5. A freshman class found that an undiluted water sample had a zero coliform bacteria count. However, the 1:10 and 1:100 dilutions had uncountable numbers. They were challenged to find a palatable solution.

IV Limitations

Travel and clothing sometimes present problems. Keys are difficult to use. Teachers should emphasize general species characteristics and support the efforts of students to help them make particular identifications. Use pictorial keys if possible. Keying unknown organisms down to species often requires an expert. Don't require too much precision.

VII Bibliography

American Public Health Association, Standard Methods for the Examination of Water and Waste Water, New York, 1965, 12th Ed. pp 634-690.

Detailed description of various collecting devices, counting cells, procedures, etc.

Edmondson, W. T., ed., Fresh Water Biology, John Wiley and Sons, Inc., New York, 2nd edition, pp 1194-1197.

Discusses the collection of plankton, vascular plants, and macroinvertebrates.

Pennak, R. W. C., Fresh Water Invertebrates of the United States, Ronald Press Co., New York, 1953, pp 727-735.

Brief description of equipment and methods. Mentions kinds of organisms which can or cannot be collected. Pictures are included.

Makenthum, K. M., The Practice of Water Pollution Biology, Dept. of Interior, Washington, D. C., 1969, pp 55-65.

Very general. Covers simple techniques.

Morgan, A.H., Field Book of Ponds and Streams, G. P. Putnam's Sons, New York, 1930, pp 26-45

Very good general information on collecting & preserving. Discusses growing organisms in the laboratory.

Smith, G. M., The Fresh Water Algae of the United States, McGraw-Hill, New York, 1950, pp27-38.

Discusses collection, preservation, and methods for studying fresh water algae.

B Stream Deterioration Due to Effluents

I Introduction

The purpose of this experiment is to show the student the effect of an effluent upon the fauna of a specific area within an aquatic system. Due to the nature of this experiment these activities would take place at a secondary level; however, with minor modifications it could be used at an elementary level.

II Questions

1. To lead to the activity ask - What is an effluent?
2. Initiate the activity by posing:
   a. How could we determine the effect of an effluent?
   b. How could you collect the data?
   c. How could you compile the data?
   d. What does the data show?

      NOTE After the students have discussed the ways in which the data can be compiled introduce diversity index.
3. To continue the activity ask: Does the effluent affect the bottom dwelling organizms in a stream?
4. To evaluate the activity ask:
   a. Did the population diversity change? How?
   b. Could you observe the changes that occur without a close examination?

III Equipment

Teachers should encourage their students to develope equipment whenever possible. Bacteriological equipment may be used if students are interested in further study.

1. a plankton net
2. a Surber Sampler or a Ekmon Dredge (you can make your own quantative samplers.)
3. containers for collected plants and animals
4. lab equipment - microscope, white enamel pans, hand magnifying glasses.

IV Procedure

1. Select a stream containing at least one effluent.
2. Pick site 50 meters above and below the effluent which are suitable for your equipment. If the stream is wide take three samples at each site.
3. Place them in separate containers, identify by number, date, and temperature of water.
4. Make a map to show where the samples were collected.
5. If time permits, more than one effluent site may be sampled.
6. During warm weather, samples should be refrigiated until used in the laboratory.
7. Pour contents of each bottle into separate white enamel observation pans.

8. Begin separating, counting, and tabulating.
9. Compile data.
10. Class discussions are very important. Plan your time accordingly.

V Previous Studies

1. Some tenth grade students were amazed at the number of species contained in one square foot samples.
2. One member of the team spent an afternoon in working a method for feeding information into the computer to develope our diversity index.
3. The team selected a stream named Needleshop Brook. Upon arrival at the stream we searched for and found and effluent entering the stream. Samples were taken above and below the effluent enterance. Also, samples were taken 200 yards further downstream. Indexing indicated a sharp reduction of fauna directly below the effluent and a 70% restoration of the fauna further downstream.
4. The data collected at sites along a stream is shown in figure B-1. As the stream had effluents added (increasing site numbers) the population diversity changed.

VI Limitations

The appropriate stream may be difficult to find, within a reasonable distance from the school and in an accessable area. Clothing and footwear sometimes became a problem.

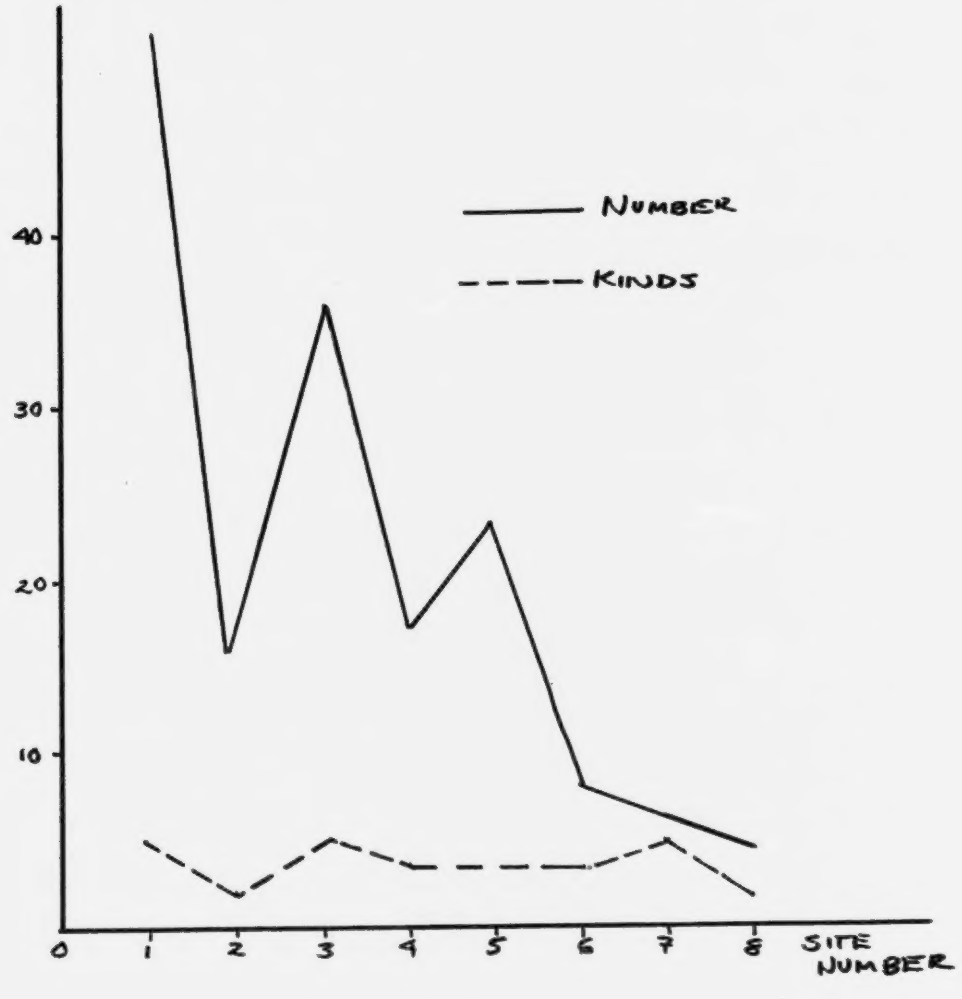


FIGURE B-1

VII Bibliography

Edmondson, W. T., ed, Fresh Water Biology, John Wiley & Sons, Inc., New York, second edition.

Pennak, R. W. C., Fresh Water Invertebrates of the United States, Ronald Press Co., New York, 1953.

Morgan, A. H., Field Book of Ponds & Streams, G. P. Putnam's Sons, New York, 1930.

Coker, N. E., Streams, Lakes, & Ponds, Harper & Row, Publishers, New York, 1968.

C. Stream Variation

I Introduction

This is an introductory activity for third through twelfth graders. The students can easily become aware of how to sample bottom organisms and how population diversity varies with water quality. A short trip to two or more sites is required but no specialized equipment is necessary.

II Questions

1. Lead the activity by asking:
   Does the diversity index change as one goes downstream?
2. Initiate by asking:
   How could we test for this change?
3. Continue by asking:
   - a. Why does the diversity change?
   - b. Does it change drastically on the downstream side of an effluent?
   - c. If so, what is the cause of the effluent and can it be stopped.
4. Evaluate by:
   - a. Listening to the ideas brought up in class discussions.
   - b. How well did the students work?
   - c. What seemed to interest them the most?
   - d. Do they follow-up on the experiment? (i.e., what is causing

the change and how could the problem be best controlled.)

III Equipment

1. Surber sampler
2. At least three 1 gallon or equivalent bottles for each sampling site.
3. Preservative for keeping the organisms.
4. Suitable clothing
    a. Boots, sneakers, ect.
    b. Shorts
    c. Rubber gloves (if working in contaminated water.)

IV Procedure

1. Collect bottom sample using the Surber sampler or another suitable collecting device.
2. Determine the number of species per unit area and the diversity index.
3. Compare and plot data of the stream.
4. Report and discuss findings.

V Past Studies

A few students at a recent water pollution conference found that the stream steadily became worse as they proceeded downstream. They noted with interest the ability of the stream to cleanse itself from an effluent if given time.

Students in a freshman science course linked the population diversity with certain other factors, such as bacteria and chemical data, and found a relationship between the three. They felt a great sense of accomplishment in the study and thought that it was a worthwhile project.

VI Limitations

Due to the nature of the experiment, the whole class might not easily do one stream, in that there would probably be too many people. It might be better to break up the class into small groups to survey other streams in order to arrive at a better picture of the aquatic ecosystem in that area. An alternative is to choose many sites along a stream.

Time is also a factor, in that field trips are generally very time consuming, as is the counting of the organisms. It is not advisable at this stage, to ask the students to identify down to the specie level, as this is not necessary.

VII Bibliography

Pennak, R.W.Cl, Fresh Water Inverebrates of the United States, Ronald Press Co., New York, 1953, pp 727-735.

Brief discription of equipment and methods. Mentions kinds of organisms which can or cannot be collected. Illustrated.

Morgan, A.II., Field Book OF Ponds and Streams, G.P. Putnam's Sons,

New York, 1930, pp26-45

Very good general information on collecting & preserving.

Discusses Bioassays.

D Diurnal Study

I Introduction

This diurnal activity deals with the study of the changes in carbon dioxide and dissolved oxygen in water over a 24 hour period by testing at regular intervals. Since the study takes place over a long (24 hour) period of time students must arrange for rest between measurements or teams must be used. The investigation should convey both the biotic processes involved in the production of carbon dioxide and oxygen and provide a situation in which the student can independently perform a scientific experiment. To accomplish this, the following objectives should be kept in mind:

1. Promote creative thinking toward the solution of a proposed problem.
2. Motivate the student into collecting date to support his program for solving the problem.
3. Encourage the pursuit of the biotic processes involved in production of the dissolved gases and their interrelationship with each other and the abiotic factors affection them.

II Questions

1. Lead to the activity by asking:
   a. Is the concentration of dissolved gases in a body of water always the same?

b. Are carbon dioxide and oxygen present in the same concentrations in a given body of water?

c. Are the concentrations of oxygen and carbon dioxide constant in a 24-hour period? or over a long period of time?

2. Initiate the activity by asking how might you determine whether the concentrations of these gases vary?

3. Continue the activity by asking:
   - a. What factors may affect the concentrations of the gases?
   - b. What effects on organisms are seen?
   - c. How does the varying concentration of gases available to organisms affect the entire community?

4. Evaluate the performance of the students by considering questions such as:
   - a. Did the students use more than one method for the determination of concentrations of gases?
   - b. Could the student offer possible explanations, reasons for his results?
   - c. Did students pursue a study of the physical factors affecting concentrations? How did they consider?
   - d. Did the student consider to effects of gases on organisms?
   - e. Did he make a study of these effects?

  f. Did he consider the effects on a community of organisms?
  g. Did he consider the effect of oxygen on food production or the reverse?
  h. Did he pursue these possibilities?
  i. How well did the students work?
  j. Were they able to relate data and for an understanding of the whole system?
  k. Did they go on to consider the seasonal effects on gas concentration and what the results of such changes might be?
  l. Does the student consider the possibility of making a general statement about the possibility of oxygen and carbon dioxide being limiting factors in an aquatic environment?

III Equipment

1. General Equipment
  a. Table for testing equipment
  b. Chairs
  c. Camping equipment, perhaps blankets, sleeping bags
  d. Large flashlights
  e. Alarm clock
  f. Food and drink
  g. Pencils and paper for recording data

h. Insecticide

i. First aid kit

j. Sponge and paper towels

k. Masking tape for labelling

2. Equipment for dissolved oxygen determination

a. Dissolved oxygen meter

b. Winkler method equipment (Have instructions available)

(1) Manganous sulfate

(2) alkali-iodide-azide solution

(3) sulfuric acid

(4) sodium thiosulfate solution (.0375 N)

(5) starch solution

(6) distilled water

(7) collection bottles with ground glass stoppers

(8) graduated cylinder

(9) burets and stands

(10) pipettes (2ml. or 5 ml. calibrated in ml.)

(11) funnels for filling burettes

(12) beakers: 125 ml. , 350 ml.

c. Hach, Delta, or LaMotte kit

3. Equipment for carbon dioxide determination

a. Collection bottles

b. Hach, Delta, or LaMotte kits or alternative procedure.

IV Procedure

1. Oxygen Determination

   a. Dissolved oxygen meter

      (1) Place probe in water by casting without allowing probe to hit the bottom

      (2) Check battery, calibrate instrument, make temperature reading

      (3) After setting temperature gauge make oxygen reading and record data.

or

   b. Follow procedures on dissolved oxygen procedure sheet (Appendix 1). For Winkler test keeping the following precautions in mind.

      (1) Becareful to use the proper pipettes for different chemicals. Marking pipettes in order to distinguish them will help.

      (2) Use care in labelling so that chemicals are not confused.

      (3) Extreme caution should be used as one handles sulfuric acid and alkali-iodide-azide solution. Pipette with CARE. If either is spilled flush the area with water.

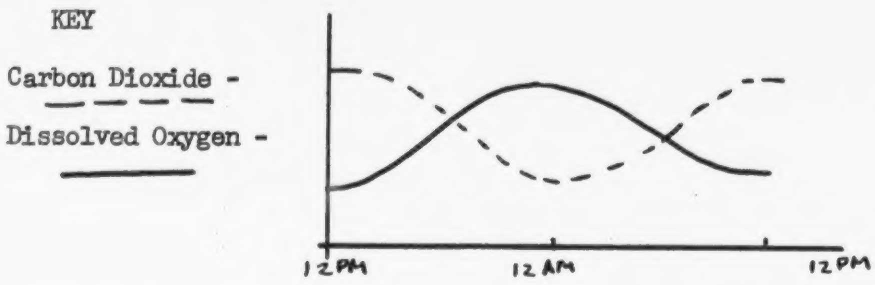
2. Carbon dioxide

   a. A collection bottle should be placed upstream in the water and it should be filled carefully with no splashing. As in Winkler, capping of the bottle should be done under water.

b. Use kit procedure to determine concentration.

V Past Studies

1. Participants in the Summer School Project at University School on a ninth and eighth grade level did a twenty-four hour study taking tests at 2 hour intervals and established an oxygen and carbon dioxide curve corresponding to the cycle.



2. Students on a junior high level participated in a 24-hour study taking the carbon dioxide and oxygen counts every 6 hours. When they found a sharp drop in the dissolved oxygen at 6 p.m. they explained it by noting the dense cloud cover that had formed since their last reading.

3. Juniors in high school conducted a twenty-four hour study during the fall and upon noticing that the dissolved did-not increase considerably from night to mid-day, they con-

cluded it was due to the leaves which had fallen and blocked the sun's rays.

4. A group from a summer water pollution program did a twenty-four hour study of a local lake and noted that the carbon dioxide curve was highly irregular. They later realized that the lighting affected the test results by giving the samples a yellowish tint thus making the color readings in the test inaccurate.

5. DO the CONCENTRATIONS of DISSOLVED OXYGEN and CARBON DIOXIDE CHANGE OVER a PERIOD of TIME

   a. Procedures

      (1) Selection of a site was made after consideration of factors including accesibility of the site and problems concerned with setting up and use of equipment. The site chosen was Webster Lake, an area directly in front of the Lodge on the shoreline of Webster Lake.

      (2) The equipment was set up inside the Webster Lodge. At two hour intervals the tests for Carbon Dioxide and Dissolved Oxygen were conducted. Two water samples were obtained by filling ground glass collection bottles with water from the site, taking care to fill the dissolved oxygen bottle complet-ly, thus preventing aeration from within the

bottle. At this time, the dissolved oxygen reading and temperature of the water were taken with the Dissolved Oxygen Meter. The Purpose of taking two dissolved oxygen tests was to make a comparison between methods. However, the Winkler-Azide Method failed to give reasonable results probably due to a fault in the reagents.

(3) Once inside the Lodge, the Carbon Dioxide test was run using the Hach Kit Method. After each test, the bottles were flushed with distilled water. (Sterility is not required in testing for dissolved gasses.)

b. Observations

As part of the observations general weather conditions are noted along with the data.

Time	Temp (oc)	O2 (ppm)	CO2 (ppm)	Remarks: (light, air temp., wind level)
10:15 pm	19	3	8	Dark, warm and still
12:15 am	19	4	6	Water disturbed due to human activity Dark, cold and still
2:15 am	18	3	8	Same as 12:15
4:15 am	17	5.2	8	Cold, Still, Lighter
6:45 am	17	7.5	6	Same as 4:15
9:15 am	19	8	4	Water disturbed due to human activity
11:00 am	20	7.5	4	Human activity disturbed the water Light, warm, still

Time	Temp (oc)	O2 (ppm)	CO2 (ppm)	Remarks: (light, air temp., wind level)
1:00 pm	21	6.5	4	Same as 11:00
3:00 pm	21.5	7.5	4	Water disturbed by human activity Light, hot, windy
5:00 pm	23	6.5	4	Same as 3:00
7:00 pm	22	8	6	Water disturbed by human activity Dark, still, warm

c. Specific Conclusions

Dissolved Oxygen and Carbon Dioxide concentrations change as a result of animal and plant respiration and photosynthesis. It may be that the Dissolved Oxygen was low during the first testing time because the day had been an overcast one and, perhaps, less dissolved oxygen had been formed by the photosynthesizing plants.

Dissolved oxygen concentrations is inversly proportional to temperature change. For example, between five and seven P.M. there was adecrease in temperature accompanied by an increase in dissolved oxygen. The wind, which increased surface water motion, may have been lower had we tested at greater depths.

d. General Conclusions

Dissolved Carbon Dioxide and Oxygen vary in concentration within a twenty-four hour period due to a variety of physical characteristics which change as the day progresses. It would be interesting to determine whether this flucuation in gas concentrations might produce noticeable effects in the biotic community of the lake.

VI Limitations

1. Make sure the equipment is complete to prevent the neccesity of returning to the lab.
2. Plan your equipment with the physical characteristics of your site in mind. (i.e. mosquitoes)
3. Obtain some method of lighting other than lights that must be held. (i.e. a lantern)
4. Location:
    a. Have easy access to your site. Problem locations would be:
        (1) forest with dense undergrowth
        (2) steep banks
        (3) water which drops off quickly at the banks
    b. Locate your site and set up equipment before dark.
5. Surviving the night:
    a. Proper clothing, a change of clothes and a sleeping bag are needed to insure the semi-comfort of the particpants.
    b. Quick energy food is needed.
    c. In most cases, insect repellent is a must.

VII Bibliography

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Ecology, Life Series

Tilton water pollution program description of the Winkler-Azide test

E. Population Diversity Index

I Introduction

This activity enables the student to determine what the species population of macroinvertebrates in a stream are. The student may also determine by investigation if the diversity index changes as one samples at random sites downstream. The activity will acquaint students with macroscopic sampling techniques, and will hopefully provide them with results that will initiate other kinds of water quality tests and activities. Seventh graders and above may do this activity.

II Questions

1. To lead to the activity:
   a. How many kinds and numbers of macroinvertebrates are in the stream?
   b. Do you think this diversity index should change as you go downstream?
2. Initiate the activity with:
   a. Where are they found and how can they be collected?
3. Continue with: if there is a change in the diversity index, how can you account for it?
4. Evaluate the students by asking:
   a. How many species were present in the students samples?
   b. Were the samples representative?
   c. Given the change in the diversity index, did the students account for this change?

d. Were the students interested in the activity?

e. Did any of the students want to pursue the activity to a greater depth?

III Equipment

1. Basic Introductory Level

   a. Hip boots, screen; (for bottom dwelling organisms - close mesh); or cloth i.e. nylon

   b. Collecting jars, with perservative, if it is being used; shallow pan; and forceps.

   c. Pan with white background.

2. More Advanced Level

   a. Server Sampler (for other samplers see Standard Methods pp. 673-83)

   b. Can to rinse attached invertebrates to bottom of net; collecting jars; shallow pan; forceps.

   c. Pan with white background; key to identify invertebrates.

   d. Dissection scope to facilitate identification.

IV Procedure

Choose several sites randomly spaced along the stream. At each site take three samples such that the area is well covered. Water should not be too deep or too shallow and fast running. Avoid large rocks; find gravelly bottom with hand-sized stones or little larger. Try to make each sample site the same type of bottom and same area.

1. For Basic Level

a. Place screen, so that it will trap macroinvertebrates that have been loosened from upstream, at the chosen sites. Disturb bottom by moving stones above screen. Note: Area should be constant for all sampling done. It may be desirable for students to wear boots.

b. Remove organisms from screen, placing them in a suitable container.

c. In the lab, place the specimens in pan with white background; separate them as to kinds andnumber. (This will determine species population)

d. Assign letters to the specimens, each specimen having a letter, with specimens in each group having consecutive numbers. For example, if there are 37 worm-like specimens, with black heads, these might be in Group A and have numbers 1 through 37; 14 snails of one type might be Group B and have numbers 38 through 51, and so on.

e. Randomly select (by putting numbers in a hat and pulling them out, for example) numbers 1 to 200 and list them.

f. To determine the number of "runs" (the numbers of continuous series of similar organisms). If the numbered specimen is in the same group as the one immediately proceeding, it is part of the same run; if not, a new run is started (It does not matter that the specimen is part of a run three or four runs back; we are concerned only with the specimens immediately following one another) For example, take the following list, with groups assigned. Suppose, that the first number chosen is #10. Number 10 organism is from Group A. This will begin run #1. Organism number 3, chosen next is of the same Group A and is therfore also included in run #1. However, the next organism, #6, is of Group D. Hence, a new run, #2, has begun. The remainder of the runs are formed in a similar way.

Organism number	Group	Run
10	A	1
3	A	
6	D	2
7	B	3
2	A	4
5	C	5
4	C	
9	B	6
8	B	
1	A	7

These are a total of 7 runs in the 10 specimens listed.

g. The total number runs reported Both as total no./200 specimens and as a Diversity Index.

$$\text{D.I.} = \frac{\text{number of runs}}{\text{number of specimens}}$$

2. For Advanced Level

   a. Place Serber sampler in water at chosen sampling site. Pick up stones and remove organisms so that they will flow into the collecting net. Note: Be sure to collect all possible organisms in the square foot area.

   b. Remove sampler from water and transfer organisms to collecting bottles. Note: It may facilitate transferring organisms if the organisms are first placed in a shallow pan and then in the collecting jars.

   c. In the lab, place the specimens in pan with white background; differentiate them as to kind and total numbers of each kind.

   d. If the students are interested, they should identify the organisms they have collected with the aid of a dissection scope and a key. (This would be for advanced students and would be useful to relate organisms being found at different sites on the stream).

   e. To determine the diversity, one divides the number of types by the square root of the total numbers of individuals for all samples taken at each site.

$$D = \frac{S \quad (\text{\# of Species})}{\sqrt{n} \quad (\text{total \# of individuals})}$$

For further interpretation of data consult The American Biology Teacher Patterns of Numberical Abundance of Animal Population, by Jerry Wilhm, March 1969, Vol 31

#3 p. 147-150.

V Previous Studies

1. A Freshman class sampled 22 different locations on a watershed; collected and massed the macroinvertebrates.
2. A 2nd year Biology class used this method to determine species diversity.
3. A field study of this type was used by sophomores, to illustrate the numerical abundance of a population of grasses on a lawn.

VI Limitations

Ample time should be provided for collecting of samples. Sites should be well planned before class activity. Since this activity will probably take longer than one setting, specimens may be kept in preservatives until time allowed; however, it is best to work with live samples (they can be kept up to four days by refrigeration). Time is required in transferring the specimens from net to jar (they tend to cling to the net). Often there is a feeling of inadequacy and a consequential fear to try this activity. If many samples are obtained, they should be clearly labled to avoid mixing; keys are often difficult to apply.

VII Bibliography

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2. Makenthum, K.M., The Practice of Water Pollution Biology, Dept. of Interior, Washington, D.C., 1969 Gives a semi-complete listing, but if you want more information on sampling methods you are asked to see standard methods.
3. Pennak, R.W.C., Fresh Water Invertebrates of the United States, Ronald Press Co., New York, 1953.
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5. The American Biology Teacher, March, 1969, Volume 31, #3

F Bioassay

I Introduction

In order to determine the effect of harmful dissolved solids on a microcosm, the minimum lethal dosage must be determined. This can be done by experimenting with different concentrations of dissolved solids and noticing the effect over determined periods of time. Seventh graders and up may complete this activity.

II Questions

1. Lead into the activity by asking:
    a. How could we test the stream's fauna in relationship to abioti factor?
    b. Are certain combinations of chemicals synergistic?
    c. How could we test for this?
2. Initiate the activity with:
    a. Where could the experiment be best controlled?
    b. What type of test organisms would be best suited for our study?
3. Continue with:
    a. What do the varying "kill" times indicate?
    b. How could this (kill time) be minimized?
4. Evaluate the students by considering:
    a. Do the students "stick with it" when the control dies off first for some strange reason, yet still continue anew?

b. Time was used wisely (as opposed to hacking)

c. Did the students try to do as quantatative study as possible?

III Equipment

Like many other experiments in the ecological perspectives group, the following materials are fairly standard. The following pieces are for a quantatative rather than a qualatative study.

1. battery jars
2. graduated cylinders
3. airators and plastic tubing
4. test chemical
5. test animals (fish, macroinvertebrates, plankton)
6. nets
7. lables and markers
8. sample jars
9. water from which samples are taken

IV Procedure

1. In the lab, mark all battery jars used.
2. Prepare each jar with the liquid required. REMEMBER the Control!
3. Begin to aireate the jars 30 min. before you put in any of the test animals.
4. Collect test animals. (Be sure that they climatized to the

lab.) For further precautions see the limitations section.

5. After the test animals are accustomed to the lab., transfer them to the test jars.
6. Note the time. Depending upon time limitations, you may want to check the jars every ½ hour to every day. (obviously the ½ hour is more quantatative than the daily check)
7. Remove all dead fish from the jars
8. For each jar graph fish kill to time of individual deaths.
9. After 96 hours or 100% fish kill, which ever comes first, end the test.

V Past Studies

Using the procedure above, studies have been done as to the effects of an endotoxin produced by the dying of certain blue-green algae. The algae were killed by copper sulfate at 4 pm. The test animals were fish of the minow class. The first study did not succeed due to the use of distilled water instead of stream water. A second study was immediately undertaken using the above procedure.

Another group of students ran a toxicity test on $CuSO_4$ and found that after 3 hours a 100% fish kill was achieved.

VI Limitations

In doing Bioassay one must keep in mind some of the following factors.

1.Temperature

2. Oxygen

3. Nutrients

As a safeguard against possible killing of the fish in the lab., try to make the water in the battery jars the same temperature as was found in the stream. Even more important is the oxygen. Remember that the fish need O_2 so try to get them as quickly as possible back to the lab to the aireators. Stream water is chosen in lieu of distilled for it was discovered that the fish would die fairly quickly without the necessary nutrients, even though the O_2 and temperature were okay.

As mentioned before time is a very important factor in that there is a considerable amount of time taken up in catching the test organisms.

VII Bibliography

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A general text on the identification and classification of fresh-water algae.

APHA, AWWA.WPCF, Standards Methods., American Public Health Association, Inc., 1740 Broadway, New York, 1950

Gives the standard tests for CO_2 as well as giving identification plates of some fresh water algae. . . . . . .

G PLANKTON GROWTH IN RELATION TO LIGHT

I Introduction

The purpose of this activity is to discover what relationship, if any, exists between the presence of light and algae growth. Students make a photometer, then use it to measure the extinction of light in a still body of water. Data from the light measurements are then compared to data on the plankton population of the water. This activity is most successfully performed by students in grades 7-12, and requires that the students have a basic understanding of the process of photosynthesis.

II Questions

1. Questions leading into the activity:
   a. What do green plants need to grow?
   b. If they don't get what they need what happens to the plants?
   c. What happens if a plant can get all the water and light it can use?
   d. What happens if a plant can get all the light it needs but can't get enough water?
   e. What happens if a plant can get all the water it needs but can't get enough light?
   f. Where is a place where plants can get all the light they need, but not enough water?
   g. Where is a place where plants can get all the water they

need, but no light?

2. Questions initiating the activity:
   - a. In a nearby still body of water, as you go towards the bottom do you reach a point at which there is no light, or less light, than at the surface?
   - b. How many plants would you expect to find there (at the bottom) as compared to the number you'd find at the top?
   - c. a) How are we going to prove that there is a place in the water where there is less light?
     - b) How are we going to prove that in this place where there is less light, that there is also less plant-life?
3. Questions which continue the activity:
   - a. Does anybody know how to snag up a lot of plants from the water at a particular depth?
   - b. Does anybody know any ways to measure how much light there is in a given place?
   - c. If you had a camera light meter, how could you use it under water?
   - d. If you didn't have a camera light meter, could you make a simple instrument to measure light under water?
   - e. What else can you think of besides a light meter that would be sensitive to light?
   - f. How could you arrange to have a known amount of plant at a known depth so that you could measure the light the

plant took in?

4. Questions to evaluate students'efforts

   Does the student have a reasonable understanding of the way in which plant growth is dependent on light?

III Equipment

1. Pond or other suitable body of water.
2. A boat, pier, bridge, or bank which will allow students to lower samples to a depth which will demonstrate a measurable extinction of light.
3. A light sensitive device such as:
   a) camera light meter in plastic bag or similar water-proof container and device (such as diving mask) for reading light meter underwater.
   b) homemade photometer: an instrument of this sort can readily be assembled with a variable-register photocell and an ohm-meter from the school physics lab. The photocell can be purchased for a dollar or less from a local electric supply house. It usually comes with two wires attached. If the wires are clipped to the leads of the ohm-meter, light registers directly as (milli)ohms of resistance. Plastic bags or other water-proofing can be applied as necessary, a project which can be readily completed with the assistance of a Senior physics student or a general science instructor.

4. Equipment for collecting plankton:
    - a) plankton net
    - b) homemade device such as cloth bag or pillowcase on coathanger frame dragged through water on a string.
5. Microscope for observing plankton
6. Measuring instrument for determining depth
    1. meter stick
    2. knotted or marked cord
7. Containers for samples

IV Procedure

1. Select a site.
2. Measure light at depth. Readings can be taken continuously or at whatever intervals are convenient from the surface to the bottom or point of extinction of light.
3. Collect plankton at depths corresponding to depths measured for light intensity.
4. Evaluate plankton population at each level.
5. Graph and correlate data to demonstrate relationship between light and plankton growth.

V Previous Studies

In a study done by students at Peasoup Pond in Franklin, New Hampshire, it was found that only 5% of the light striking the surface of the pond penetrated to a depth of four feet. Near the surface of the pond several types of green algae were present in moderate concentration; no algae was found in samples taken at a depth of four feet.

VI Limitations

The pond used for the study has to demonstrate enough extinction of light so that there will be a measurable difference in plankton concentration from the surface to the bottom. If the water is too clear, plankton will avoid the very bright sunlight in the upper 1-2 feet of the pond and figures could be produced that would show increasing plant growth with decrease of light. A very deep pond or lake which was stratified for temperature could show a difference in photosynthesis on opposite sides of a thermocline.

VII Bibliography

Fresh Water Algae of the U.S. p. 14 & 15
by Albert Smith
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Fundamentals of Limnology
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H Water Quality Comparisons by Diversity Index

I Introduction

The purpose of this investigation is to compare the diversity index of two separate waterways; one with obvious pollution, the other apparently clear. Suitable locations may be found through observation of the site, comparing basic properties; noticeable fish kills, sewer or drainage pipe entering lake, noticeable algae blooms, odor of water and lake shore. Young students could do a fair job with sample collecting, but perhaps only high school students should attempt complicated type classification.

II Questions

1. To lead to the activity, ask how many kinds of plants and animals are present at this location.
2. Initiate the activity by posing, how are you going to collect these specimens?
3. Continue the activity with:
    - a. Does the water depth have any affect on the numbers and kinds of organisms present?
    - b. Does pollution affect the total number of animal and plant samples collected?
    - c. Are there any specific plant or animal groups that are affected more than the others by pollution? (This may be a benefit as well as a detriment)

4. Evaluate the performance of the student by considering questions such as:
    a) Did the group collect a good representative sampling of the area?
    b) Did all students appear to be working willingly, and to their capacity?
    c) What part of the investigation seemed to interest them most?
    d) Were the students able to draw adequate conclusions to satisfy the problem?

III Equipment

Equipment can easily be adapted to availability. Even for advanced groups sophisticated equipment is not needed.

1. fine mesh cloth to filter bottom samples for microbes.
2. screening to screen out larger invertebrates.
3. seines, or fish nets, to collect small fish or aquatic insects
4. containers for holding plant and animal specimens
5. a small rubber boat or raft (any floating craft that will hold one person)
6. meter stick for measuring depth of water
7. sounding rope
8. microscope

IV Procedure

1. collect all varieties of plants present at a shallow depth

2. Seine or net samples of small fish, amphibians, water insects, or other forms of animal life at shallow depths; up to one meter
3. screen out large invertebrates from soil samples at shallow depths with coarse screening
4. examine the lake bottom, at shallow depths, for bottom dwellers; snails, clams, mussels etc.
5. if the group is mature enough--repeat procedures (C&D) listed above, at water depths of two and three meters.
6. bring material back to laboratory, sort as to like kinds, and classify all specimens where possible.
7. compare collections from each site, and determine the effect pollution has on organism diversity.
8. within each waterway, determine what affect water depth has on numbers of individual specimens

V Previous studies

1. A group of high school students were surprised to find that the number of mussels per square meter was greater in a polluted lake than in a non-polluted one. This led to speculation as to how far this pollution could go before the trend was reversed.
2. In comparing lake bottoms from polluted and non-polluted water systems, the students noted that polluted sand bottoms were covered with a layer of silt or mud; the clear

lakes had much less sediment. They wondered whether the increased vegetation could have anything to do with this situation.

3. The presence of large masses of Spirogyra in the shallows of a still lake became a signal to a sixth grade class that the water was polluted.

VI Limitations

Class size may hinder effective control and accomplishment of this investigation. Transportation is always a problem. In studying water that shows pollution signs, care must be taken to protect the student from contamination. If adequate protection is not available, then the site should be ignored. Classification should be attempted according to the ability and maturity level of the class. Keying to Class or Order is adequate for younger groups.

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4. Pennak, R.W., Fresh Water Invertebrates in the U.S., The Ronals Press Co., New York, 1955
   A good guide to the fresh water forms most often found in common waterways of New England. Keys are quite easily followed for younger students
5. Prescott, C.W., How to Know The Fresh Water Algae, Wm. C. Brown Co., Dubuque, Iowa, 1964
   A rather comprehensive and difficult key to the algae of fresh water. The practiced student has little or no trouble finding most species.
6. Smith, G.M., Fresh Water Algae of the U.S., McGraw Hill Co., Inc., New York, 1950.
   A complicated key to the algae; not to be used by the inexperienced student.
7. U.S. Dept. of the Interior, Biological Field Data for Water Pollution Surveys, Supt. of Documents, U.S. Printing Office, Washington, D.C. 20402, 1966
   A good book for terminology and equipment description for water sampling. Could be helpful for even the very young student.

I Algal Blooms and CO_2

I Introduction

The purpose of this investigation was to determine the regularity properties of CO_2 in relationship with algal blooms. It might be best handled by students that have taken either biology or chemistry. This could also be handled, although maybe at a less quantatative level, by those who have not yet had such courses. The test is conducted by running CO_2 and algae counts and plotting the resulting graph between the two.

II Questions

1. Lead the activity by asking:
    - a. How do plants affec the life in a given body of water?
    - b. What do the plants need for growth?
    - c. What gases do plants give off?
    - d. What gases are utilized by the plant in the photosynthesis process?
2. Intitiate the activity with:
    - a. How could we test for these gases? (i.e. why test for them?)
    - b. Would there be a relationship between the amounts of certain gases and the amount of algae?
3. Continue the activity with:
    - a. Could these gases be controlled?
    - b. Does an algal bloom control the CO_2 or the CO_2 control

the bloom?

4. Evaluate the students by considering:
    - a. Do we have enough data to reach a valid conclusion?
    - b. Did the students understand the procedure?
    - c. Did they try to refine the procedure in its rough spots?
    - d. Were they inspired to take on new outgrowths?

III Equipment

1. Basic level
    - a. Method for testing CO_2 (Hach, Delta, Lamotte, etc.)
    - b. Sample bottles
2. More advanced level
    - a. Same as above plus bioassy equipment using plankton as organisms.

IV Procedure

1. Basic Level
    - a. Take CO_2 test.
    - b. Take water samples for plankton analysis.
    - c. Count the plankton.
    - d. Graph the results: number of plankton to corresponding CO_2 levels.
2. More advanced level
    - a. Same as preceding procedure
    - b. Run a bioassay using plankton as test organisms.

c. Purpose: to create an algal bloom.

d. Introduce CO_2 into the system at different levels.

Sophisticated equipment is neither needed or desired. Availability should determine usage.

1) fine mesh cloth to filter bottom samples for microbes
2) screening to screen out larger invertebrates.
3) seins, or fish nets, to collect small fish or aquatic insects
4) containers for holding plant and animal specimens
5) a small rubber boat or raft (any floating craft that will hold one person)
6) meter stick for measuring depth of water
7) sounding rope
8) microscope

IV Procedure

a) collect all varieties of plants present at a shallow depth.

b) seine or net samples of small fish, amphibians, water insects, or other forms of animal life at shallow depths; up to one meter.

c) screen out large invertebrates from soil samples at shallow depths with coarse screening.

d) examine the lake bottom at shallow depths, for bottom dwellers; snails, clams, mussels etc.

e) If the group is mature enough--repeat procedures (C&D) listed above, at water depths of two and three meters.

f) Bring material back to laboratory, sort as to like kinds, classify all specimens where possible.

g) compare collections from each site, and determine the effect pollution has on organism diversity.

h) within each waterway, determine what affect water depths has on numbers of individual specimens.

i) keep close tabs on the pH

j) test for CO_2 changes

k) discuss the importance of a rise or fall of CO_2 in the system.

l) Graph and plot the resulting data.

V Past Studies

Some students while investigating the first question noticed in their study that certain data when plotted showed an interesting bell-like curve. This curve indicated a high and/or low range in which algae might exist in bloom conditions. Time ran out before sufficient data had been collected in order to answer the last question.

Other students, for a recent lab-report undertaken in a tenth grade chem. class ALSO STUDIED THESE QUESTIONS. They found that there was certain limitations in running a bioassy in the lab using CO_2 as a nutrient. The lab was not a true success in that the test organisms died due to the increase of pH caused by the added CO_2. This did, however, force them into the field where they found varying concentrations of CO_2 occuring, naturally. This then made them ask themselves as to why the pH was not so high in the ponds and lakes as in their bioassays. Thus they are hot on the trail for a possible buffer existing naturally in the water.

VI Limitations

The main limitation in the excersive lies in the advanced level of the experiment. That is, the CO_2 levels in the different jars were of such concentrations that the CO_2 in the water caused a significant rise in the pH. This is due to the carbonic acid that is formed when CO_2 changes to carbonic acid. This is why it is felt that a suitable buffer needed...

Another important limitation is that most CO_2 tests are no more than a free acidity test in that phenolphthalene is the Indicator. Therefore if the sample that you are working a test for have a higher than a pH of 9, any CO_2 that is present will be masked by this alkalinity. Perhaps a possible outgrowth of this could be a chemical that would percipitate the carbonic acid out of the water which then could be measured.

VII Bibliography

1. Smith,Gilbert M., The Fresh-Water Algae of The United States, McGraw Hill Book Company, New York, 1950
A general text on the identification and classification of fresh-water algae..

2. APHA,AWWA,WPCF, Standard Methods, American Public Health Association, Inc., 1740 Broadway, New York, N.Y., 1965 pp 78-85, 739-744.
Gives the standard tests for CO_2 as well as giving identification plates of some fresh-water algae.............

J. Bottom Core Sampling

I Introduction

This activity is designed to aquaint high school students with bottom sampling in general and organic analysis of bottom samples in particular. Approximately 3 one hour periods will be required. The setting for the investigation should be one which will enable the student to obtain a core with relative ease as well as a core which will evidence clear layering from season to season. Generally the best locations are around bodies of water which undergo regular flooding every spring and gradual emergence during the summer month. The dark layer which will be noted usually represents the rather fine organic material that is deposited in the shallow and calm waters of the summer season while the alternating band of coarser and lighter colored gravely material is representative of sediment which is laid down in the more turbulent waters of the springtime.

It is important that students practice taking cores beforehand and develop skill in driving the core sampler and retrieving the samples. See Figure 3J-1

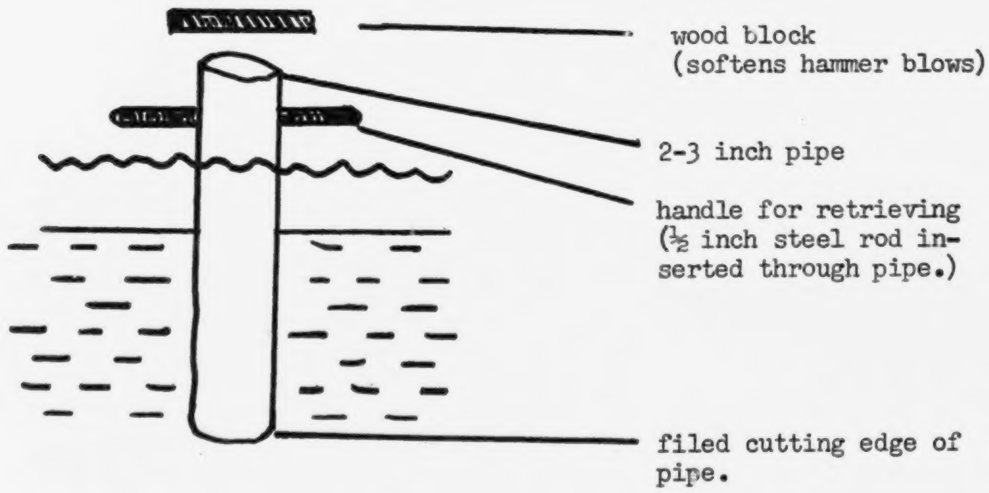

wood block
(softens hammer blows)
2-3 inch pipe
handle for retrieving
(½ inch steel rod inserted through pipe.)
filed cutting edge of pipe.

Figure 3J-1

II Questions

1. Lead to the activity by asking:

   Can you think of any way to obtain a record of some of the materials which have been suspended in our streams and lakes and deposited on the bottom over the past several years? Explain.

2. Initiate the activity with:

   Do you feel that the amount of organic material being laid down each year in a specific body of water is related, in some way, to the amount of pollution that this area has experienced? Explain.

3. Continue the activity with:

   Can you think of several different ways to analyze chemical variations and interpret the ecological history which is indicated in core samples? Explain.

4. Evaluate the students work by noting what signigicant differences they discovered in the different layers and by evaluating how they reconstructed the ecological history.

III Equipment

core sampler, large flat cake pan or other suitable pan for placing the core to be analyzed, drying oven, spatula, cm ruler, Merck burner (bunsan burner may be used if a Merck is not available), ring stand, triangle extra large crucible, size 3, (an evaporating dish may be used if a cruicible is not available), centigeam balance.

IV Procedure

1. The core may be obtained and removed immediately by gently sliding it out onto a cake pan.
2. After bringing the sample to the lab select the areas for analysis. Cut sample bands of desired width (approx. 1 cm.) and place each band to be analyzed in a previously weighed crucible.
3. Dry sample at 70-80°C in an oven overnight to remove moisture. (An alternate method of drying is to line the core tube with vaseline before the sample is taken and allow the sample to dry in the tube over the weekend or for 2-3 days and then remove. The core then has less tendency to

fall apart in the removal process. The outer edge in contact with the vaseline must be shaved off before analysis.)

4. Weigh each crucible and dried sample.
5. Heat sample for 45 min. to burn off all organic material. (If the art department has a firing oven the sample may be fired until it comes to constant weight).
6. Cool and weigh.
7. Heat again for 15 min., cool, and weigh. If weights agree within ±0.03 grams, the sample can be considered to be at constant weight. If sample is not at constant weight heat, cool, and weigh until it is.
8. Determine the weight of sample.
9. Determine percentage of organic material.

V Past Studies

A Core sample was obtained for the first site of the Winnipesaukee River. Although several cores were obtained only one was used for analysis due to limited time. Choices of where to take samples from the core will vary from sample to sample according to mud stratification. In our sample, layers of similar given grain size (finess) were chosen. We used bunsen burners for heating and glowing embers were noted in the samples up to 30 minutes after heating began. Our samples were left for 2 hours and the second heating gave constant weights. No effort was made to determine minimum heating time with bunsen burners. Heating time would vary anyhow according to the percentage or organic material present. The following results were obtained.

Sample	location on core	% organic material
A	1st cm from top	4.9%
B	2nd cm from top	2.2%
C	11th cm from top	1.5%
D	12th cm from top	3.1%

From this one test no definite conclusive interperations can be made. Since class investigations would be expected to produce more analyses, the significance of any patterns which might develop should be interpreted with respect to the ecological history of the area.

VI Limitations

1. Heating to burn organic materials may require much extra time depending on percentage of organic material present and how hot a flame is available.
2. If cores are obtained with no stratification it is difficult to determine where to take samples.

VII Bibliography

A constructive approach to pollution problems requires more than a knowledge of pollution results; we also need to understand the human motives and action that produce them as well as comprehend the political process that we must iniciate to change those results. It is difficult to define or limit the scope of the activities which appear in this section, for in a general way virtually all human activity is either social or political.

There are several general approaches that may be taken in this chapter, however, one of the most direct approaches to the social and political factors is to begin with the present, find out how we got here and where we ought to go from here. To find out where we are the student must begin to relate the scientific aspects of pollution to the social and pollitical factors. The question"where are we now?" must be answered as completely as possible. Our political institutions must be defined and evaluated to see what hope for solutions lies in them. Existing laws must be examined as well as procedures for enforcement. In other words, the political structure at all levels must be examined to determine what type of vehicles exist and what in fact is going on. This in itself is not an easy task, some of the activities which follow, such as the construction of government models, clearly demonstrate the overlaps in authority, and the ambiguous seats of responsibility which now exist among government agencies.

Next, to determine what factors allowed this situation to develop, it is beneficial to undertake a study of the history of our laws and those political institutions relevant to water pollution as well as the feelings and sense of responsibility among various individuals and companies. The history of the relevant laws is easy to determine through research. Most states have law librarys available to the public or any other law library such as is found in a local court house, unniversity or even a local attorney's personal library. Any of these is a good place to begin.

Of particular value is the history of the development of industrial polluters. Each business can be analized from many points of view. Its health record in terms of water pollution violations, which is obtainable from the state pollution commission or whatever body charged with the regulation of water quality in your state, of particular interest. The economic history of a company can usually be determined by studying past annual stockholders reports and corporate histories available either from the company itself or through a local brokeage house.

The state engineers associated with water quality can be queried and corporate excutives should be questioned. They are able to relate past, present, and future policies of the corporation in terms of their responsibility to stockholders, the community in which they operate and the natural resources they consume or destroy. Very often decisions made by management concerning natural resources are made according to narrow economic criteria which are at best inadequate. They are often not conscious that any decision they make concerning the management of natural resources involves the allocation of the essentially fixed resource.

Activities which involve personal interviews are very valuable in demonstrating the difficulty in reaching solutions when the problem involves particular people whose rights, prejudices and very often simple lack of interest must be taken into consideration and dealt with. Very often games, particualrly those which utilize roll playing, are also helpful in further illuminating these conflicts.

In conducting these interviews students may ask questions which probe at other competing considerations for the use of our resources.

This brings the students to the last phase of investigation: "where do we go from here?" Do we have an obligation to future generations to maintain the quality of our natural environment and, if so, how do we go about preserving it! The model legislation activities as well as the formation of clubs and Lobbies are helpful in focusing attention on specific problems.

Another aspect of this section involves communication. Environmental problems which already exist as well as those which are impending must be recognized and widely discussed.

Possible alternatives must be made known before any final decisions concerning our natural resources are made. If a lobby is to be successful, it must have wide support; if model legislation is to be enacted, it too must have the support of citizens and legislators alike. All of this involves communication of one kind or another. Students are more than willing to undertake activities in this area and may utilize any media from vidio tape to statistics.

A. How To Talk Back To Statistics *

I Introduction

This activity is designed to help students read articles on water pollution critically; the activity should also help them increase their general awareness. Select the articles according to the groups reading ability and their scientific background. Don't unerestimate the students ability to follow news articles; they are very curious about news.

II Questions

1. To lead to the activity, ask:
   a. Is the information you read in your article reliable?
2. To initiate the consideration of the statistics reliability, ask:
   a. Who says so? (Where did the data come from?)
   b. How does he know? (Qualify the source)
3. To continue refining the evaluation of the article ask?
   a. What is missing?
   b. Did somebody change the subject?
   c. Does it make sense?
4. To evaluate the students success, check the following:
   a. The student should formulate an opinion on the article and back up his views with several important

factors.

b. The student should be able to present the complete subject in an acceptable manner.

c. The student should be able to demonstrate particular types of distortions or misusage of data by converting the data to a low quality advertisement or poster.

III Equipment

Materials for writing and illustrating should be available. Copies of the article must be made or bought. If the students rework the data, serious consideration should be given to publishing their work.

IV Procedure

1. Get an article, make copies, and assign the reading.
2. Have a class discussion where you introduce the questions.
3. Let the students do another rendition or let the students seek out several views on the same subject and then reapply the questions to be able to compare the articles.

V Previous Studies

Seniors were required to subscribe to the New York Times. They were required to read front page articles which dealt with statistics or data. They could be counted upon to read about drugs, economics, and, in particular, water and air polution. After reading 3-5 articles and evaluating them the critical evaluation based on the five questions become automatic. A carryover into the evaluation of advertisements was notable. When students presented data as a result of polls they had taken, usually they did not do a superficial job. This could carry over into lab conclusions and evaluations.

VI Limitations

Reporduction of articles for educational purposes is usually permissible. Make it a policy to acknowledge sources and, when possible, tell the author you used the material for educational purposes.

VII Bibliography

Freund, John E. Modern Elementary Statistics, Prentice Hall inc. Englewood, N.J., 1960. This text acquaints students with the theoretical aspects of statistics. Recommended for high school students.

* Huff, Darrell, How To Lie With Statistics, W. W. Norton and Co. 1954. This book is a study of the use and misuse of statistics. It is written in a humorous style and can be understood by junior high students. It is recommended for all who undertake this activity. Available in paperback.

Johnson, D.A. and Glenn W. H., Webster Publishing Co. 1961. The World of Statistics. A book on the

basics of statistics for junior high on up.

Reichman, W.J. Use and Abuse of Statistics, Oxford University Press, New York, 1962. A general work on statistics designed for the high school student which covers the calculation of statistics and their use and abuse.

B. State and Local Government Organization

I Introduction

This activity is to introduce any junior high or high school student to governmental structure on a state and local level. As a result of this activity, the student should know where to go in his local or state government to deal with a water pollution problem. Students will probably develop a schematic diagram to display the governmental breakdown. This activity may be done by any student above the 7th grade.

II Questions

1. After arriving at a site of water pollution, ask the following questions to lead to the activity:
   a. Do you see anything at this site which is an indication of water pollution?
   b. What are some possible sources?
2. Initiate the activity by asking:
   a. What do you think we as a group can do to stop this?
   b. Do you know the legal restrictions concerning water pollution?
   c. Where would you find them?
3. Continue the activity with:
   a. Are you able to correlate the information you have found?
   b. How could you ressolve the problem of organizing the

information?

c. Would a visual aid be more feasible for total group comprehension?

4. Questions which help the teacher evaluate the student's efforts:

a. What iniative do the students show in responding?

b. How do they perform as a group and as individuals?

c. Does the schematic accomplish your objective?

III Equipment

1. Use of school library
2. Pamphlets released by Legislative Services, Comptroler's Office, and Water Pollution Board.
3. Poster board, pens, magic markers, and rulers.

IV Procedure

The students should be taken to one site and a particular pollution problem pointed out. The local area should be scanned beforehand for various pollution offenders along bodies of water. The school itself determines whether the students can find the necessary source material themselves or whether these need be placed in the library prior to the time of the activity. Such things as proximity to state agencies and class schedules will help in determining which course of action should be taken.

Either through use of the library or student investigation the students will obtain information concerning state laws and state agencies. Hopefully their research will lead to questions concerning the state agencies dealing with the water pollution aspect. They will discover the necessity of understanding a relationship between the various state agencies in order to deal with them more effectively. At this point the teacher may suggest a schematic diagram for student use.

Students may show interests in other aspects and this interest should be encouraged. The following areas may be used for future activities or the students may wish to work in groups on some or all of them.

1. relationship of federal and local agencies
2. operative effiency of state commissions
3. students devise their own schematic which may be more effective than the present state organization
4. state, federal, and local laws dealing with pollution
5. biological studies of pollution
6. social aspects

V Past Studies

Students and teachers at the Tilton School Water Pollution Program, made a study of this sort during the summer of 1970. They visited the state capitol at Concord and the students and teachers obtained information from the general Court Manual and antiquated schematic diagrams. After visiting many governmental departments, they settled upon the basic agencies which could be helpful. After establishing their way around, the students conducted interviews with the comptroller to find where the money came from and how it was spent, on a state and local level. Then, they proceeded to make a schematic diagram of the government, making a second and more technical one of the water pollution department. When presented with a hypethetical problem that involved working through the government the students showed greater interest and ability to analyze because of their increased grasp of the governmental organization obtained through this activity. Figures 4B-1 through 4B-3 show the results of the study by a ninth grader.

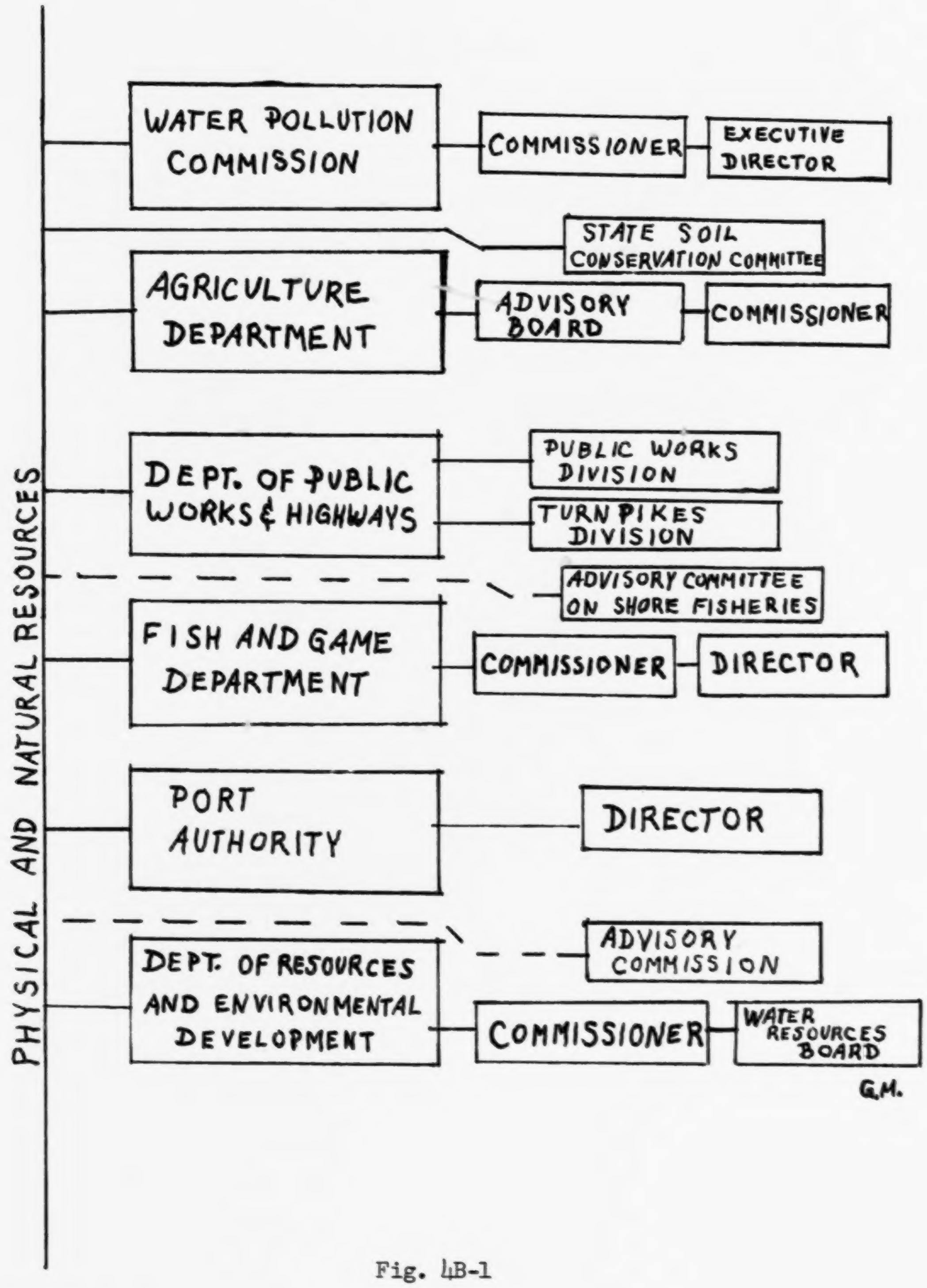

PHYSICAL AND NATURAL RESOURCES
WATER POLLUTION COMMISSION
COMMISSIONER
EXECUTIVE DIRECTOR
STATE SOIL CONSERVATION COMMITTEE
AGRICULTURE DEPARTMENT
ADVISORY BOARD
COMMISSIONER
DEPT. OF PUBLIC WORKS & HIGHWAYS
PUBLIC WORKS DIVISION
TURNPIKES DIVISION
ADVISORY COMMITTEE ON SHORE FISHERIES
FISH AND GAME DEPARTMENT
COMMISSIONER
DIRECTOR
PORT AUTHORITY
DIRECTOR
ADVISORY COMMISSION
DEPT. OF RESOURCES AND ENVIRONMENTAL DEVELOPMENT
COMMISSIONER
WATER RESOURCES BOARD
G.M.

Fig. 4B-1

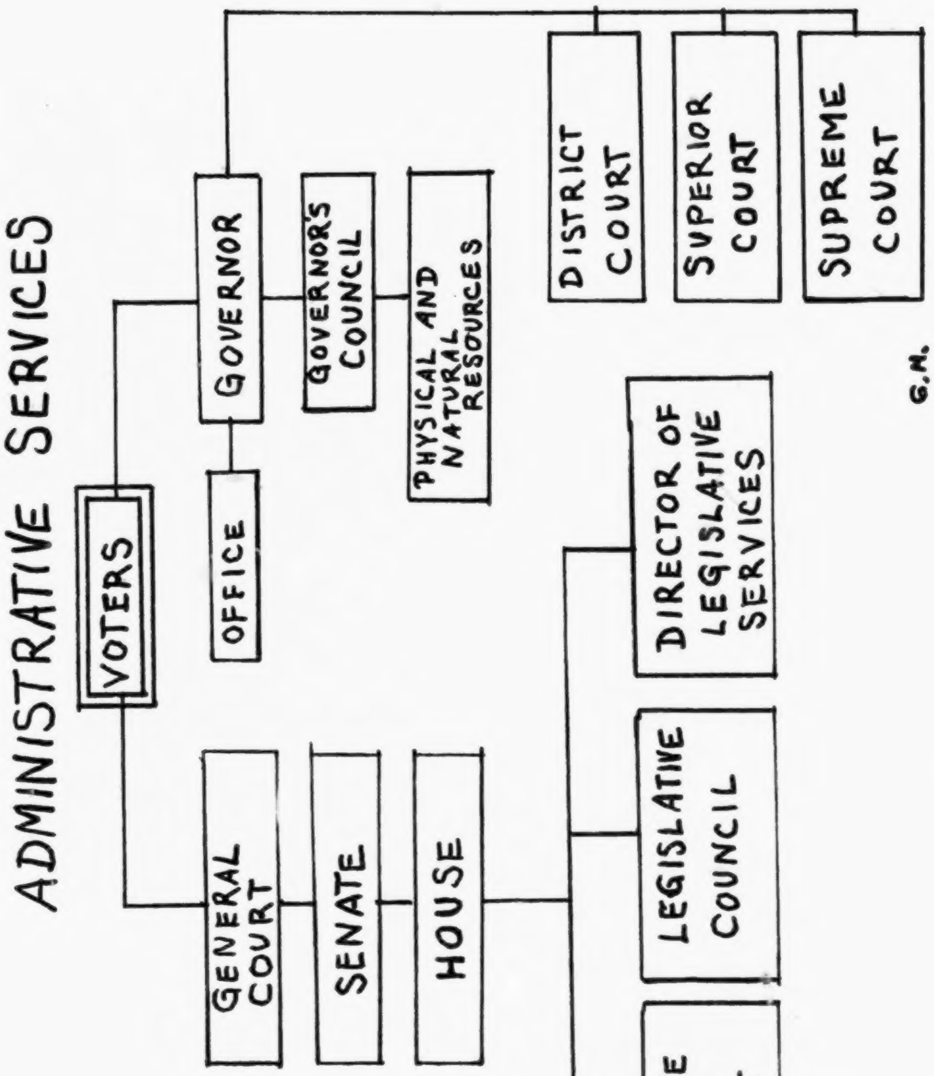

ADMINISTRATIVE SERVICES
VOTERS
GENERAL COURT
SENATE
HOUSE
LEGISLATIVE BUDGET ASSISTANT
LEGISLATIVE COUNCIL
DIRECTOR OF LEGISLATIVE SERVICES
GOVERNOR
OFFICE
GOVERNOR'S COUNCIL
PHYSICAL AND NATURAL RESOURCES
DISTRICT COURT
SUPERIOR COURT
SUPREME COURT
G.M.

Fig. 4B-2

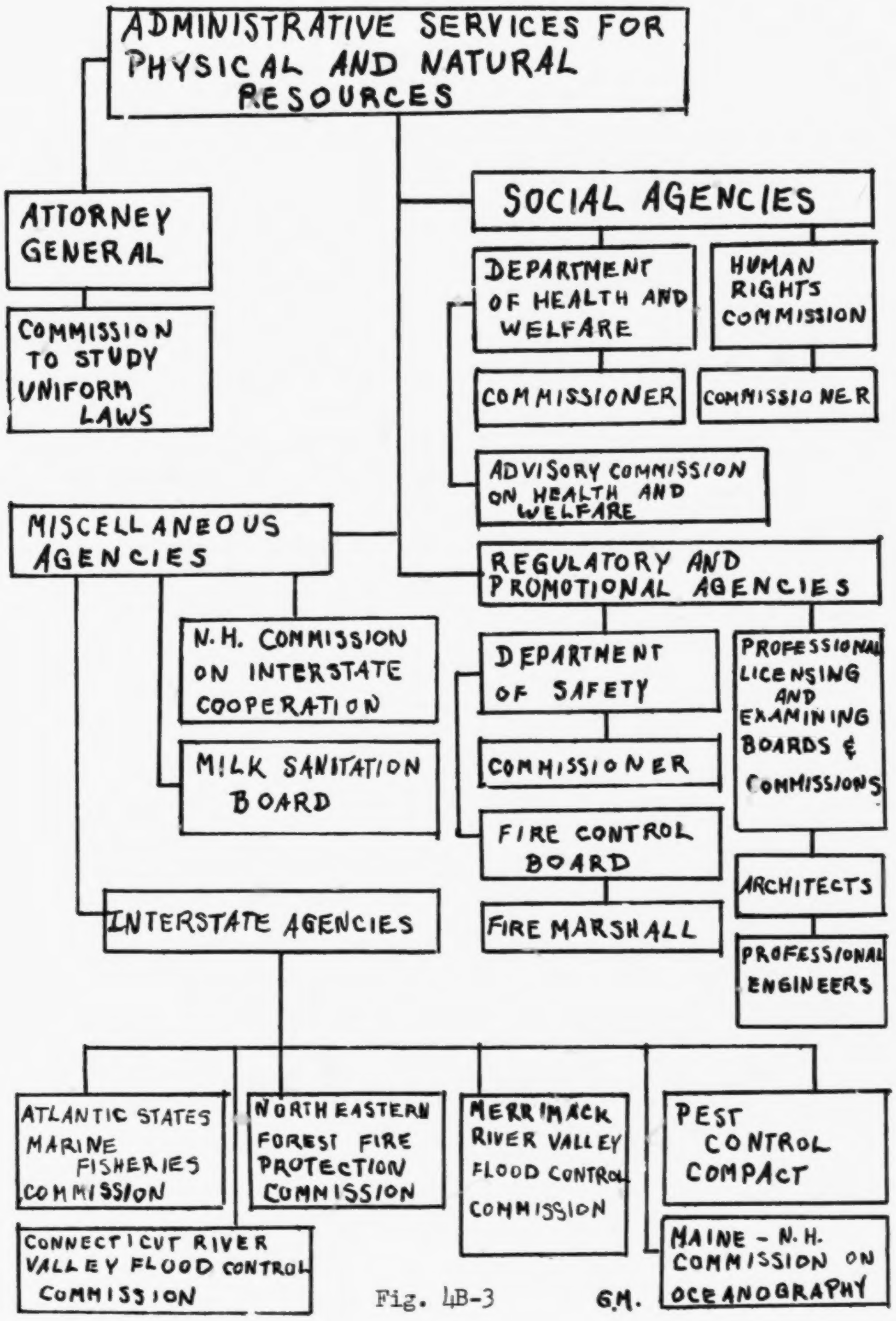

ADMINISTRATIVE SERVICES FOR PHYSICAL AND NATURAL RESOURCES
ATTORNEY GENERAL
COMMISSION TO STUDY UNIFORM LAWS
SOCIAL AGENCIES
DEPARTMENT OF HEALTH AND WELFARE
HUMAN RIGHTS COMMISSION
COMMISSIONER
COMMISSIONER
ADVISORY COMMISSION ON HEALTH AND WELFARE
MISCELLANEOUS AGENCIES
REGULATORY AND PROMOTIONAL AGENCIES
N.H. COMMISSION ON INTERSTATE COOPERATION
MILK SANITATION BOARD
DEPARTMENT OF SAFETY
COMMISSIONER
FIRE CONTROL BOARD
FIRE MARSHALL
PROFESSIONAL LICENSING AND EXAMINING BOARDS & COMMISSIONS
ARCHITECTS
PROFESSIONAL ENGINEERS
INTERSTATE AGENCIES
ATLANTIC STATES MARINE FISHERIES COMMISSION
NORTH EASTERN FOREST FIRE PROTECTION COMMISSION
MERRIMACK RIVER VALLEY FLOOD CONTROL COMMISSION
PEST CONTROL COMPACT
CONNECTICUT RIVER VALLEY FLOOD CONTROL COMMISSION
MAINE - N.H. COMMISSION ON OCEANOGRAPHY
G.M.

Fig. 4B-3

REV:JT:3:A:1

VI Limitations

This activity could vary, from an hour to several days, according to the students' desire to delve into such a project. If the instructor gathers certain information ahead of time, it is possible to work within normal class periods. Transportation could be a problem for those wishing to visit a state capitol, if it were far away, or other government organization.

VII Bibliography

Pamphlets published by the state, or local governments are useful. New Hampshire Publishes, through the department of state, A Manual for the General Court. Any reports by temporary advisery commissions are also valuable.

C State Government Model

I Introduction

This is an activity for the high school level which could follow one in which the state government structure in the area of water pollution has been studied (such as Activity B, in this chapter). It is assumed that the students have been impressed with the complexity of governmental operations; the duplications of efforts; the inefficiencies of the various bureaus, commissions, boards, etc.. It is therefore anticipated that the students might wish to develop their own organizational plan for water pollution control. The students may then wish to make suggestions to their legislators or to special appointed task forces so that the immediate serious problems might be solved by minimizing the usual red tape and delays.

II Questions

1. Lead to the activity by asking:
    - a. Why does it take so long to get things done?
    - b. Why is it so hard to get questions answered?
    - c. Are you surprised by the complexity of the structure of the state government?
    - d. Do you think the present one can operate efficiently and effectively?
    - e. Do you notice that various aspects of the water

pollution program come under different agencies?

2. Initiate the activity with questions such as:
    a. Name all the people and organizations that might be concerned with water pollution.
    b. Do you think that certain areas are not covered?
    c. Do you think that efforts are being duplicated?
    d. Do you think that you can come up with a better type of organization?
    e. What are some desirable changes that are in order?
    f. How do you think that the changes can be brought about?
3. Continue the activity by asking:
    a. Now that you have developed a plan which you think is more efficient and effective, do you wish to pass this on to your legislators?
    b. Name some other individuals and organizations that might be interested in your plan.
    c. If no party or parties show any interest in your plan, do you wish to revise or alter the plan?
4. Evaluate the students' efforts with questions such as:
    a. Did this activity interest the students?
    b. Did they wish to extend the study?
    c. Did they really feel that they were making a contribution to the solution of the problem?

III Equipment

No equipment is needed. Various booklets on the structure of state governments - from the state in which the school is located or (if a boarding school) from home states. Typewriters, duplicating or copying machines are in order.

IV Procedure

1. After students have expressed their dissatisfaction with the present system of water pollution control, suggest (or have the students suggest) that they develop a better system which would more efficiently coordinate all the agencies, commissions, etc.
2. Have the students block out a table of organization.
3. In New Hampshire compare the students' plan with the one proposed by the governor's Task Force.
4. Suggest follow-up by writing letters and enclosing the plan to legislators and others who might be interested.
5. Students may be encouraged to make charts and posters explaining what they hope to accomplish.

V Previous Studies

1. Studies of government structure in other courses might have given the students an idea of the complexity of government structure.
2. Experiences in the past in seeking out information,

such as letter writing and interviewing might give clues to the problems involved.

3. Some students may have experienced the feeling of powerlessness; the credibility gap; and the great difficulty in getting direct answers to questions.
4. The bibliography contains a list of documents acquired in two days at Concord, N.H. Three tries were required to obtain the Table of Organization and it was three years old.

VI Limitations

The only limitation is the time factor. This activity really cannot be confined to one hour and a half. Depending on the type of course that is being offered, this activity can be as short or as long as desired, provided that the interest is there. It is possible to go on to another unit while replies to letters or any follow up studies which are underway.

VII Bibliography

State of New Hampshire Citizens' Task Force
    Over-all Report
    Reports of the Consultant
    Reports of the Subcommittees
State of New Hampshire Citizens' Task Force Chart of the
    Reorganization of the Executive Department,

Concord Daily Monitor, Jan. 7, 1970

State of New Hampshire Table of Organization of the State Government

State of New Hampshire Table of the Organization of the Water Supply and Pollution Control Commission.

D. Anti-Pollution Laws

I Introduction

This activity is designed to determine what circumstances are operating in a given area which allow cases of obvious pollution to continue to exist. While it is true that the time gap between creation and enforcement of laws is one of the primary causes, this is not always the case. If anti-pollution laws do exist, it may be the case that a gap also exists between what is generally considered to constitute pollution and what legally constitutes a case of pollution--in other words, both legal and illegal polluters have been found to exist.

In order to make such discoveries, the students are required to wade through many legal documents as well as carry out interviews. Therefore this activity is suggested for senior high school students.

II Questions

1. Lead to the activity by asking:
   - a. Why isn't something being done about citing a local polluter
   - b. How can you determine the legal status of an industrial?
2. To initiate the activity ask:
   - a. What agencies (public and private) are directly con-

cerned with industrial pollution in your river basin?

   b. Which ones make the regulation?
   c. What are they?
   d. What people should be contacted for information? local? state? federal?
   e. What questions do you want answered? For example, is there a water quality standard in your state?

3. To continue the activity ask:
   a. What types of testing have been done?
   b. Should you make tests of your own?
   c. Who interprets the results of the testing?
   d. What is the mechanism for reporting violations?
   e. How do you survey local industry?
   f. What steps are they taking toward sewage abatement?
   g. Who is responsible for enforcement of water pollution regulations?
4. To evaluate the student consider:
   a. Whats types of background material did the student gather?
   b. Were the questions formulated in advance of personal contact with resource people?
   c. Was the plan of attack well planned and viable?
   d. Can the student differentiate between legal and illegal

pollution practices?

e. Is the student aware of public recourse that can be brought against the illegal industrial polluter and the steps in this process?

III Equipment

No special equipment is required unless the students do testing in the field.

IV Procedure:

1. Select a sight of obvious water pollution.
2. Determine the industrial or private persons who are contributing to the pollution.
3. Investigate the local, state and federal agencies concerned with pollution in your area and determine what laws are now in existence.
4. Select one specific industrial polluter and secure background material on the corporation., ie.
    a. How is it polluting and do what degree. (may be necessary to perform tests).
    b. When did they begin?
    c. How many people employed?
    d. Gross earnings.
    e. What responsibility do they feel they have?
5. If a violation is occuring, dicuss the courses of action regarding it. You may want to do one of the following:

a. Go to the corporation and speak to someone in charge about their responsibility to meet legal atandards, their past actions and projected activities.

b. Go to the local polititions about the specific corporation.

c. Go to the relevant enforcement agencies with your data and attempt to find our what they are doing.

VI Limitations:

You may have difficulty arranging interviews. Some people are reluctant to talk freely about the situation. This often includes politicans, factory managers, and heads of agencies on all levels.

Conflicting evidence may occur in the data collected by personal interviews. Biases and backgrounds of the persons being interviewed should be taken into account.

Interpretations of the law may be a problem at times even for the "experts".

If violations are found and reported, don't expect instant action. Legal mechanisms might very well be in low gear.

V Past Studies.

This activity was carried out by a group of students at Tilton School. A small industrial polluter was discovered along the Pemigiwasset River in Franklin, N.H. and tests above and below the tannery were made to determine the exact nature of the water pollution. It was discovered that the tannery was polluting beyond the limits set by the state Water Pollution Control Commission, the city manager of Franklin, N.H. and the manager of the Verza Leather Co. Although a violation was found to exist, the state allowed this until completion of sewage abatement.

VII Bibliography:

This is the bibliography acquired by the Tilton study.

Camp, Dresser, and McGee, REPORT ON SEWERAGE AND SEWAGE TREATMENT, CITY OF FRANKLIN, NEW HAMPSHIRE, January, 1965

A consulting engineering firms report on the treatment of this city's municipal and industrial sewage.

State of New Hampshire, LAWS RELATING TO THE WATER SUPPLY AND POLLUTION CONTROL COMMISSION, January 1970

U.S. Department of the Interior, Federal Water Control Administration, REPORT ON THE POLLUTION OF THE MERRIMACK RIVER AND CERTAIN TRIBUTARIES, PART 1

Contains the summary, conclusion, and recommendations for the cleaning of these rivers

Personal interviews with a member of the Water Pollution Control Commission (Mr. Town), the city manager of Franklin, N.H. (Mr. McSweeney), and the manager of Verza Leather Co. (Mr. Smith)

E. An Elementary Investigation of Local Water Anti-Pollution Programs, by Interviewing Government Officials

I Introduction.

This activity could be used in classes for sixth through twelfth grade students. The students should become aware of the local problems in their communities and develop an interest in the problems. The interview might take longer than an hour. This activity evaluates the evident effectiveness of the government to deal with water pollution.

II Questions:

1. Lead to the activity by asking what the water pollution problems in our community are?
2. Stir interest by asking:
   a. Who are the people responsible for controlling these problems?
   b. Do they use the authority given them, effectively?
3. The teacher may evaluate the activity by considering:
   a. What were the student results?
   b. What reasons were there for these results?
   c. Were the students' questions well prepared?
   d. Was the students' back-up knowledge sufficient?

III Equipment

None is required.

IV Procedure

1. Find out a few problems in your community by reading the newspaper.
2. Determine which laws pertain to these problems.
3. Make up an outline of questions.
4. Set up the interview.
5. Record the results and your reactions, by writing articles or reports.

V Past studies

This outline was followed for interviews involved with pollution problems in two communities on a sixth grade level. Problems were encountered in dealing with community officials. The following reaction was written as a result of a three day trip to Washington to find out what was going on. The article appeared on pages 75-77 of the March 1970 issue of the Academy Science Journal published by Germantown Academy, Ft. Washington, Pa.. The authors were seniors in 1970.

Moving Around on Pollution

On March 4th, a Wednesday, four leaders of the Wissahickon Lobby met with Professor Zandi of the University of Pennsylvania; Ecology Department. The professor is an authority in matters of pollution and its treatments. Another meeting took place on March 6th, with Samuel S. Baxter who is the Commissioner of Philadelphia's Water Department. Both interviews were very educational and further indicated the number of highly paid pollution fighters who are sitting around doing nothing.

Mr. Zandi was very impressed with the enthusiasm of the Wissachickon Lobby; however he seemed to be very pessimistic as to any positive results. Mr. Zandi suggested some kind of coordinator or advisor who could tie all the lose ends together. It is important to note that Mr. Zandi did not have all our material and therefore could not review the situation to its furthest point. One must also take into consideration the role of the University which is purely educational. Your might call it a non-involvment policy. Mr. Zandi proposed that he would come to our school once a month and check the projects progress and offer his advice. There was no settlement as to the future, however Mr. Zandi said he would look into a student advisor on a weekly basis (senior doing graduate work in actual pollution).

Our interview with Commissioner Baxter dealt more with the legal aspects of pollution. He is presently involved with an article entitled "Are Things As Bad As They Seem"? Mr. Baxter felt there were many other problems that were more pressing than the problem of pollution. He posed questions such as, "Many people want all the streams and waterways as clean as possible, can the 4 million people living in metropolitan Philadelphia expect to physically clean up the streams"? Mr. Baxter is in a bind as are all officials handling this problem, however; is this a valid excuse for the hording of enthusiasm.

The shortage of money was brought up by the Commissioner, but how is it that a newly formed lobby such as ours is capable of raising money and not a large scale organization such as The Philadelphia Water Department? It also seems as though the people themselves are aiding the various extents of pollution by rejecting any increase in taxes for the fight against pollution. Many enjoy the reduction in taxes due to the amount paid by the companies who must pay taxes because of the pollutants they feed into the air and the water. It has even been mentioned that various people don't want anything done for that specific reason. I'd say that was a little selfish on the people's end of the pole. Will it take a critical situation to move people or can we join in and work at it now???????

Mr. Baxter's problem is much more complexed than the one we have here at the Wissachickon and this makes ours much easier to clean up. An example would be the storm sewage problem they have in the city. After it rains much waste and pollution is carried into the sewars, however it only amounts to 3% of the Delaware Rivers Pollution. For the city of Philadelphia to clean that 3% up, it would cost approximately 3 billion dollars. In 3 years the Department has spent 75 million dollars on working in treatment plants. This is all very impressive, but somehow something can be done on the

Wissachickon that is not going to cost 75 million dollars. The Wissachickon is no Delaware River, however; if we were situated on the Delaware, the impression that was made by certain figures would have been much less agreeable...

Our feeling is one of optimism and the problems of the larger scale pollution fighters do not neccessary involve us. With the number of students we have working on the Lobby and the amount of information we have piled up, one can't help but look at things in a bright light. Things are moving and the right people (industrial and sewage polluters) are now beginning to worry, is there a better indication??

Bill McKay '70
Sal Siciliano '70

The following reaction was written as a result of a trip to the capitol of Pennsylvania. It was a research trip for a student lobby. This article appeared in the December 1969 issue of the Academy Science Journal, published by Germantown Academy, Ft. Washington, Pa..

Pollution and the Law

On November 26, 1969 I traveled to Harrisburg to interview a Mr. Smurda of the Department of Health about water quality. My reason was to gather legal data on the relation between water quality and the law. My hope was to find out the different legal ways in which to help my school in its attempt to unpolute the Wissahickon Creek. As my interview went on I was increasingly impressed that though there are laws, there in no real way to stop filth from being poured into our streams unless the companies decide to do something on their own.

The first thing which I was showed, was a copy of the laws as they now stand. I immediately turned to the page which told of the penalties for constant waste disposal into streams and found the following:

> Any person who shall continue to discharge sewage or permit the same flow into the waters of the Commonwealth, contrary to the preceeding provisions of this act, or after the expiration of the time fixed in any notice from the board to discontinue an existing Discharge of sewage into the waters of the Commonwealth shall, upon conviction thereof in a summary proceeding, be sentenced to pay a fine of not less than twenty-five dollars and not exceeding one hundred dollars for each offence, and a further fine of ten dollars a day for each day the offense is maintained and, in default of the payment of such fines and costs, the person or the member or members of any association or co-partnership, or the officer or officers of any corporation, responsible for violation of this act, shall be imprisoned in the county jail one day for each dollar of fine and costs unpaid.

The part of this which is most distressing is the fact that a smiple appeal can delay indefinetley the payment of fines which might even reach a meaningful size in the area of 10,000 dollars or more.

For the most part the rest of the articles which I was shown offered little that those people at my school did not already know. All the figures that I saw agreed with our own and showed that many levels including the total soluble phosphate level is 500% (approx.) higher than it should be.

The one thing that I think really struck me was that the State knows who is poluting the creek and even go to the trouble of listing who these people are. This was the list as taken from the implementation plan for interstate waters Schuylkill river basin.

Industrial Wastes -Discharges

Nicolet Indust.
Certainteed
Lansdale Tube-Philco
Merck, Sharp & Dohme
Precision Tube
Leeds and Northrup
Philco-Ford TV
McNiel Labs.

Sewerage

Ambler MSS

Sewerage, con't

Ambler South MS
North Wales MSS
Abington T. MSA
Gwynedd Jr. College
Silverstream Nurs. Home
Del. Val. Ind. Sew.
Selas Corp.
Aidenn Lair
Up. Gwynedd T. MSA
Sheraton Motor Inn

The most distressing thing is that the State knows who is throwing things into our creek and yet they can do very little. Something must be done within the near future and it must be done by the people involved. If reform cannot come fast enough from the Government, cooperation must come from all involved.

Nick Bachrack, '70

The following article appeared in the February 1970 issue of the Academy Science Journal, published by Germantown Academy, Ft. Washington, Pa.. The author was in the class of 1970.

Washington Excursion

This was the first trip to Washington concerning federal anti-pollution laws and programs. We entered Washington with a navie attitude that people would be eager and willing to help us, but when we left we realized the problems that confront an anti-pollution program.

The first obstacle to overcome is getting an appointment. Time can be lost if this is not done before arriving in Washinton. We lost one afternoon of work because we did not have a definite appointment. A definite time and day will resolve this problem.

Another problem we incurred was that we can be given the run around quite easily. To solve this problem we need somebody, inside Washington or out, who is able by his name to get us action. At this point, only a few people seem interested in what we have to say. The only two places where we found any interest were Mr. Cutler of Senator Muskie's staff and Representative Coughlin's office. In both these places, we found people willing to listen and talk with us. Mr. Cutler was helpful by naming other people we could contact for help; these were Thomas Jarling - Minority Counselor Public Works, James Smith- Conservation Foundation in Washington, League of Women Voters and the administration.

We should not, however, look to Washington as our sole means of help. Although it is nice help from Washington, we must start looking around us for help because this is where we can apply the most pressure. We should look for a group to help us. If there are none, we should form one. This can be done in several ways. One way, that Mr. Cutler agreed with, was an association. This association would be made up of schools from through out the Delaware Valley. With business and community backing, we can use this group to get things done as well as applying pressure. We can also join lobbies in both Harrisburg and Washington. Being part of a lobby will also bring open doors and bring us more power.

Mr. Cutler also stated that unless the waters we are investigating are interstate, we must work within state and local laws. If the waters are interstate, then it comes under federal jurisdiction.

Although the trip was not a complete success, we did learn something. The next group that goes down must be ready before hand. They must have specific questions to ask and definite appointments. They must be ready to be given some run around, but also they should realize it and try to stop it. We must also get contacts in Washington who can help us get appointments in Washington.

Pieter Platten '70

VI Limitations

There might, in some large cities, be a problem in getting an interview. And, many times one official will refer you to another, which makes things difficult for reasons of transportation and time.

VII Bibliography

English teachers generally can provide a bibliography which gives references on writing reaction papers.

F. Publication of a Science Journal

I Introduction

This activity introduced the student to the communications aspect of pollution studies. A science journal is as one key to reaching other people through students' activities. This project would involve more than Science; English, History, and Art departments are important contributers to the overall results. The student is eager to share his enthusiasm and ideas with others, resulting in a spreading involvement in pollution activities. Grades 7 through 12 will find this a good activity. In one case a second grade remedial reading class made a significant contribution to one science journal.

II Questions

1. To lead to this activity ask students if they feel there exists a need for communication concerning pollution.
2. Initiate the activity by asking the students what method they consider most appropriate for the establishment of communication. And whether or not a science journal would help in creating an awareness of the problem?
3. Continue the activity by asking to what activities could the establishment of a journal lead.
4. The activity is easily evaluated by the continuance of the journal and determining:

a. Is there an interest on the part of the students to participate in some way in the production of the journal?

b. Are they concerned about communicating their ideas with others?

III Equipment

Equipment requirements vary according to resources available. Your journal could be a mimeographed series of reports stapled together or a sophisticated, printed manual. You will need paper, typewriters, mimeograph, stamps and envelopes for mailing, and people to work.

IV Procedure

Suggest to students that they write up their various activities and collate them into a booklet. Devise a method to choose eight or nine students who will be in charge of general production such as reader service, editing and correction articles, and collating material. A suggested mailing list would be the area independent and public schools. This type of activity allows for participation of students of all ages. Perhaps, if you have the time and the materials, you can print copies for parents and alumni, in order to generate interest. Encourage every student to contribute, not necessarily scientific articles, but ones dealing with pollution in general.

V Past Studies

Germantown Academy, Ft. Washington, Pennsylvania, last year started production on the Academy Science Journal. Nine students from the Biology 2 section were in charge of general production and the first issue of articles were contributed by the Biology, Physics and Chemistry departments. However after a couple of issues, students non-scientifically oriented were contributing write-ups on projects and activities, varying from the invention of a flow meter to first grade essays on the meaning of pollution. Artistic students contributed diagrams, drawings, and cartoons. The Journal's content increased in size slowly; however there was more variance within the composition. Eventually they were sold for a quarter a piece to members of the local Watershed Association to raise money for some projects. The students in grades 1-5 were so enthused that they made a booklet of drawings and essays on pollution and sold them to buy a filter for the school incinerator. The Academy Science Journal is printed monthly and contains 80 typewritten pages; it is distributed to approximately 200 schools free of charge. The purpose of the Academy Science Journal as stated on the title page is:

> As faculty of the science department of Germantown Academy, we uphold the belief that many of our students

are capable of making significant scientific contributions at the secondary level. These students possess the initiative and scientific curiosity to determine problems, conduct research, and translate the information into meaningful conclusions.

We feel that their investigations warrant publication in order that others may share in their activities.

VII Bibliography

Examples of science journal on any level make up the best bibliography. Check with your school librarian.

G. Orientation Program For the Study of Water Pollution

I Introduction

This activity is set up as a discussion for a group orientation to the study of waterpollution. The group can be a traditional class. It could also be a community group, e.g. students from several high schools that do not offer a course in Water Pollution. The questions should stimulate the group into shaping a skeleton from which the leader can plan a study agreeable to all. It would be helpful to get through the whole activity in one session. However, the rate of progression must be determined by the group. Tape recording the discussion would have value, so the group leader could use it as a reference in the future. The questions are set up under the precept that the group will be situated by a polluted body of water. Perhaps it will be the one the group decides to study. This natural setting should act as a motivating device, as seeing the problem would increase awareness and hopefully concern among the group.

II Questions

These questions are here to provide thought provoking topics for discussion. The first three sections play a specific role in the progression of the orientation.

1. To lead into the activity- These questions are

here to "set the stage." They are intended to lead the group into an atmosphere of concentration on the subject of water pollution. They lead into the real investigation.

a. What is pollution?

b. Can you indentify by sight any pollution in this water?

c. Are natural things, like leaves and twigs, pollution?

d. How is a scientific approach to the problem relevant?

e. What can science tell us about the problem?

f. Can this information help us to solve the problem?

g. How can data and facts help us?

h. Why is a social approach important?

i. How can a social approach help to solve the problem?

j. How can public relations help with a commercial approach to fighting pollution?

k. On which commercial enterprises should there be focusing?

l. What type of public relations are important?

m. Reflecting recent months, pollution plays an important role in politics. How can politics influence pollution?

n. How can his outlook on pollution affect the fate of a politician?

2. To initiate the activity- The trend should be set in a meaningful direction at this point. Discussion now centers about the objectives of the group. These shall be recognized by covering the points to each numbered theme question.
    a. Should we study a specific body of water?
    b. What would you like to find out about the pollution of this water?
        - -chemical
        - -bacterial
        - -historical
        - -aquatic life
        - -public influence
    c. Are we going to try to solve the pollution problem?
        - -(apply what was discussed in A)
        - -when
    d. How shall we divide the group, if at all?
        - -scientific
        - -social
        - -commercial
        - -legislative
        - -political

e. Whom shall we involve in fighting this pollution?

- -peers
- -family
- -community

f. What type of information shall we request?

What commercial enterprises shall we contact?

- -only water polluters
- -any polluters
- -research agencies
- -factories
- -small enterprises

g. What information shall we seek?

- -history
- -general information
- -a role we can assume now

h. What shall our group objective be?

- -(tie together what was discussed)

3. To continue the activity- Now that the atmosphere is set and the group objectives recognized, these questions shall focus on planning the group's activities. The extent of the use of the questions will vary, especially in the case of high school students. Many will have to have been answered by other than the

group in preparation of a type of contract, be it a community group.

a. Where shall we begin?

- (introduce limitations set by authorities, be it necessary)
- frequency of group sessions
- (summarize B and make it concrete)
- independent work
- funding
- publicity

4. To evaluate the students performance- These questions can be applied to a classroom situation if the need for an evaluation persists. If it is a community group, this evaluation will probably be unnecessary. The leader will have to evaluate a group of high school students if their schools request it. Evaluation may also be necessary if credit is to be given for the study.

   a. Did the group member help set a meaningful trend to the discussion?

   b. Did he (she) make specific personal objectives of the study?

   c. Did he (she) help with the setting of the group objective?

d. Did he (she) introduce relevant discussion matter not included in the outline?

III Equipment: The equipment used should be decided by the leader. Some may prefer to keep the whole orientation a discussion. Others may find (preferably) non-scientific aids helpful. Listed below are a few suggestions:

1. Should the students desire to observe the water more closely, the following supplies may prove useful:

   -bucket
   -rope
   -hand lens
   -old cloth (as a net)
   -tin cans
   -plastic bags
   -jars or bottles

2. Current mass media about pollution may or may not prove helpful through the orientation.

IV Procedure: Begin the orientation with the questions, Although they need not be carried out exactly, the questions are prepared to facilitate discussion of relevant matter. The leader must "play it by ear", as each group will be directed differently.

V Past Studies:

1. A discussion held in the natural setting has proved

effective at Grymes Memorial School, Orange, Virginia.

2. The Role Play technique has been used with great success at Nottingham Academy in Buffalo, N.Y. Its use fosters understanding of various situations and opinions among students. It is a technique especially good for a student who refuses to understand a situation.
3. It is important that the students have an understanding of the problem of pollution. A raw scientific approach without any orientatin is more apt to "fail" than a study where the students actually understand the significance of any scientific methods before they begin.
4. Notice the word leader is substituted for teacher. A study of water pollution is something new and different to most students. It is more important to learn about it that be taught about it. However, the need for an experienced moderator still exists. This person may or may not be a "teacher". Hopefully, the teamwork that should result will put all group members on the same level, regardless of their age.
5. Role playing activities
   a. A constant consumer of high phosphate detergents arguing about detergents. (If others are introduced, the argument should become a discussion.)

(1) High phosphate detergent consumer

-if phosphates are that bad the gov't should outlaw their use

-the laundry must be clean, and there are no comparable substitutes

-phosphates tend to make the water 'wetter', and this is necessary in a hard water area especially

-I have to use up the detergents I've already purchased

(2) Anti-pollution consious consumer

-phosphates are a main contributor to algae growth and increased bacteria growth, thus causing eutrophication.

-it is up to the individual to fight pollution to the best of his ability

-which do you value more - clean clothes or clean water?

- if we don't purchase them store owners and manufacturers will act quicker

(3) Detergent Manufacturer

-research has been going on for many years.

-automatically banning phosphate detergents would present serious problems

-housewives are spoiled by modern detergents and won't settle for soap

-if housewives were really so anti-pollutior, why are they still buying high phosphate detergents?

(4) Grocery store owner

-must stock all different products so a consumer may purchase according to individual needs

-obligation to provide an outlet for manufactured products

-must not let viewpoint overpower the wants of the consumers

-competitive reasons force me to stock favorite laundry aids

b. A purchaser of brightly colored tissue products which contain non-biodegradable dyes is angry because the store she patronizes stocks only white tissue now. This is a discussion among any number of the four or more possible role players.

(1) Angry Purchaser

-these products brighten up the bathroom decor

-if they are banned, so should other luxury

items that pollute worse
- -these products are much softer
- -somebody has to buy them

(2) Anti-pollution crusader
- -unnecessary pollution created
- -white tissue products do the job just as well
- -individuals should fight pollution to the best of their ability
- -such products a waste of money

(3) Manufacturer
- -color is a way of brightening life
- -nobody is obliged to buy them
- -worse dye pollution from fabric mills etc.
- -manufacturing not stopped for economic reasons

(4) Store owner
- -color disgression is not right
- -comparable products that pollute less are still stocked
- -unsightly dye pollution is created in manufacturing-let's stop as much as we can
- -hint to manufacturers such products are unnecessary luxuries

c. A boat owner is upset with the new law concerning sewage disposal from boats. He is discussing it with a friend.

(1) The Law

-illegal to discharge sewage from watercraft into water

-head may be sealed permanently and still comply with the law

-all users of the state's waterways must comply

(2) Boat Owner

-silly law to bring sewage back to land only to receive inadequate or no treatment

-pollution control device too expensive for the seldom used head

-out of state boaters are being cheated

(3) Anti-pollution crusader

-better to have sewage cpmcemtrated than discharges throughout waterways

-other states will look up and form better standards

-obligation of all boaters to comply

The role plays should then be analized:

-did the person play their role all the way through?

-could a concensus be attained?

-were any dependencies among various roles cited?

-were resolutions suggested? could they be suggested?

VI Limitations

1. In a community group, the problem might arise of the participants not being acquainted with each other. The leader must be prepared to help resolve this problem, as a study of water pollution requires real team work. The discussion approach which this particular paper deals with should help relieve this obstacle a bit.
2. Students may have trouble understanding problems of fighting pollution. It is important they understand the viewpoints of those involved in their professions. This is an area where they assume the role of a designated position. In a given situation they are to work out a problem verbally, trying to adhere to their role, under group observation. It is interesting and often advantageous to have the students exchange roles about half way through. The examples below are representative of typical problems encountered in an effort

to fight pollution. They are accompanied by points that often occur in the situation. There are undoubtedly supplements. The points given are not paralleled.

VII Bibliography and Resources

This paper was put together by drawing on experiences. No specific references were consulted.

To initiate and sustain an activity as this, the best resources are current mass media.

H An Anti-Pollution Club

I Introduction

This activity is designed for high school students whom are interested in starting a club dealing with different facets of pollution.

II Questions

1. Lead to the activity by asking:
   - a What problems of pollution in your area would you like to see remedied?
   - b How could student action help resolve that solution?
2. Initiate the activity with questions such as:
   - a What specific aspect of possible action would your students be most interested in?
   - b What type of student or school organization would be most effective and useful to enable the students with their crusade?
   - c What angle of consideration of this aspect would be most effective in dealing with the problem?
3. Continue the activity with:
   - a Could an outside institution help the organization in any way?
   - b Could increased publicity further action or expand the program?
   - c Have all of the facets (i.e. side effects, sources, relationship to the total pollution scope, consequences, etc.) been dealt with?

d Are there any similar problems in the area?

e Are there any other schools or organizations that might need help or could benefit from your organization's experiences?

4. Consider evaluating students with questions such as:

a What did your group accomplish?

b How did the results, conclusions or experiences compare with these anticipated?

c How could the plan be improved?

III Equipment

The equipment required will be determined by the activities of the club.

IV The method for starting an organization will vary depending on the school itself and the kind of program desired. Students interested in the numerous aspects of pollution (i.e. science, legislation, philosophy, etc.) should be encouraged to participate because differing skills are needed in any project. If the students show an interest in establishing a club or similar student organization, help them out by:

1. Finding out the procedures for establishing a club
2. Defining the purpose of the club (write a charter)
3. Publicizing the club

In defining the purpose of the club, the activities that the club hopes to carry out or the possible lines of action should be considered.

After the club has been functioning for a length of time, it might be advisable to sit down an a group and list or outline the activities the group has engaged in. This outline should include the failures as well as the successful ones. From this outline, a short (a a long) explanatory program of what the club is doing could be evolved very easily.

The program could utilize any pesters and/or charts and anything else that the club has produced to explain and exemplify pollution. A slide program with a narrator and sufficient subject matter can be very effective.

Once this program (be it 10 min. or 30 min. in length) is set up it may be presented to students in other schools in the hope that they will be moved enough to form their own club.

1. Clean up of Polluted Areas

Organize a basic plan for the clean up of community rivers, streams and highways. Make use of volunteer community citizens. It is recommended that plastic or canvas bags be used for waste instead of paper bags. Review the sites to get an idea of How and What to clean up. Needed materials could include trash containers, vehicles for pick-up and transportation.

2. Underground Newspapers

Underground newspspers are effective tools for the students to work with because they are not limited by the censership of the administration. Organizing a paper that will be published regularly is a herculean task. As the group starts work on the paper they have to raise money for supplies and decide on the purpose and format of the paper. Usually money can be obtained by soliciting students and organizations. Some problems with running a paper are that the interest has to be kept up, the paper has to eventually pay for itself and the staff should be somewhat organized. Don't let people Cop Out!

3. Distribution Centers (books)

As an activity of the club, a booth can be set up and operated by the students to sell or distribute material concerning pollution. Buttons, poster, and stickers etc. can be made by the students and sold for a profit at the booth. A select number of important students can be selected to receive these works free in order to stimulate interest. Other purposes for the booth may be setting up of a center of the distribution of materials. The Federal Goverment distribution of materials in Water Pollution and related pamphlets are free upon request. A congressional record has been found to be informative. School newspapers concerned with any subject can be distributed at the booth. This keeps a constantly changing pile of materials at the booth.

4. Erosion

Find an erosion problem in your community that needs attention. Determine what would be involved to correct the problem. If its a major undertaking, seek the help of the community. If it is a small project, gather the needed equipment and materials and set up a work day for the club and other interested students.

5. Colleges and Elementary Schools

Contact colleges in the area to see how a cooperation ile. sharing data, equipment, ideas, personnel can evolve in a discipline area. Contact elementary school teachers to see how your club activities can be shared with the younger students.

6. Communication

Communication has an important role in any activity as it is necessary to make information public so that it can be effective force in the school and community. The methods of communication available are unlimited. Some of them are the school newspaper and distributing dittoed sheets at information centers. Outside of the school the students could set up an underground newspaper and talk to th local radio stations about being able to set up a broadcast.

7. Poster and Art Exhibits

For any art exhibits, space for thw proper hanging must be available. There are several exhibits made up for exhibition in school. One specific company that does this is Kodak Co. These exhibits are of photographs taken by students and judged by professionals, and rated 1st, 2nd or 3rd. You can find out about these exhibits by asking the Kodak shop or for other exhibits you may ask a local museum.

Poster contest can be sponsered in your school by the art department or the science department. All you need to do is to arouse enough enthusiusm for the project so that you have enough contestants. One idea for premeting the enthusiasm is to make materials available for the students. Often, when some kind of prize is offered, more of the older students will participate.......Otherwise, your best participants will be the students in the lower grades.

Having any kind of exhibit in the halls of a school building will help in bringing the students to gether in a group. You will be finding out that some of the students would have been unmetivated if such a contest did not arise.

8. Field Trips

Field trips are interesting and useful to a club. Areas of interest are easily found such as polluted areas of established pollution studies. But the trips should be to areas of interest and have relevancy. A certain date, time, and methods of transportation should be set up before the designated time. It is possible to get help or maybe permission from authorities if you write ahead of time or call to ask.

The purpose of the trip, either testing or knowledge-seeking can be discussed beforehand to look forkey points during the trip. In the case of testing water legal complications should be taken into consideration.

V Past Studies

1) A group of high school students in St. Louis (University City High School) set up a political newspaper, which helped to initiate some changes within the school structure.

Limitation: Initial cost for paper and motivation of student to 'stick it out'.

2) State-wide clean up of streams, river and highways in Vermont. All communities were asked to help. General agreement for future involvement evolved. People worked for a common goal becoming aware of the pollution problem.

3) Paper drive by students of the Vermont Acasemy which was publicized beforehand so people could call in. The paper was taken to a factory that reuses and pays for it.

4) Volunteering for beautification of mental retardation center. Donations were given by local florists and American Legion Post. North Quincy students; Quincy, Mass. Other students, from different schools also helped.

Limitations: Follow up is necessary to care for plants (project was stopped by school closing.)

5) Involving another school in this type of club. Atlantic High School Project was stopped by school closing.

6) At Germantown Acasemy a group of 40 to 50 students was formed to lobby the Pennsylvania State Legislature. Students soon found out that they could not be effective unless they had the facts. Several subcommittees were formed to look into the interaction of federal agencies, state agencies, and local authorities. Further interest developed in writing the history (economic and

social) of each of the polluter in the watershed. For this activity small groups of 2 and 3 (often young people who are dating each other) investigated the corporations by consulting the sanitary water board helath violation records, interviewing corporation executives and engineers, and reading annual reports and other public relations material. The resulting write-ups and block diagrams were circulated among all lovvy members. Letters were written to legislators and their reactions noted in the Academy Science Journal. As a by-product of the investigations and letters written, the school now receives 2 copies of the Congressional Record, White House press releases on ecology and and pollution, and federal legislation documentation (public laws). Many of the students reacted by showing deep interest in how you can work within the system to accomplish antipollution programs. The material they had studied in history they acknowledged to be an important part of their background, which they had not realized had existed.

VI Limitations

Often financing a club is difficult, selling buttons and stickers is a good wat to raise quick money; but, some projects are expensive and donations may be sought from local lumver companies, manufacturers, furniture companies, florists, chemical plants scientific, electronic firms and even the Army Reserve.

It is important to maintain the progrma after it is once started. Make sure that you are not doing too many things at once; if some activities begin to fade due to the lack of manpower, try to interest the students in joining the more active project. Change the pace occasionaly with money raising projects, such as a car wash to allow the students to become interested in a non-related project. Be sure that your activities are not all of the same nature. There should be at least one major action program in operation. Be sure to inject new ideas as the old activities are resolved.

Occasionaly the adminstration of a school does not endorse student programs which are destructive to the normal school routine. If you can get the administration to not only attend the meetings, but also participate in the projects closer relation will be insured.

Sometimes transportation is a factor, as well as distance. Make sure vehicles are available, that time is available to complete the project.

If space is a limiting factor, make use of homerooms, study halls etc.

VII Bibliography and References on Community Action Groups

1. Dynamics of Group Action D.M. Hall, The Interstate Printers & Publishers Inc., Danville, Illinois, 1964

This book is a handbook of group behavior. If you are originating a club or group, you will be interested in the problems of establish-ldeas, goals and objectives. It will hekp you to understand the How, Why, Who, When, What, Where, and it will show you especially How to get students and other participating. It will give you a background in both the theory and practice of group work.

2. Roberts Rules of Order Henry Martyn Robert, Scott, Foresman, Chicago, Illinois, 1915
3. Changing Human Behavior by John Mann, Chas. Scribner's Sons NY 1965

This book illustrates the problems created by advanced technology since we have been thrown together. In order to survive, we must change. The author gives the reader a background in significant attempts to assess the effectiveness of currently used behavioral change procedures. Chapter 7 is especially good in the following areas:

The effect of group size

Composition of groups

Group power structure

The effects of group discussion

Social and Political Factors Draft

- The effects of group interaction
- The influence of objective feedback
- Principles of behavior change in the small group
- Group Dynamics

Chapter 8 effects of mass media

- The lab as opposed to the field setting

Chapter 9 Attitude Changes

Chapter 10- Intergroup contact

- Implications of social action

I. How to Win Friends From Sceptics, Critics, and Doubtful School Administrators Without Really Trying.

I Introduction

This activity is designed to get students involved in a campaign to elicit interest, help, and support from these people in a school system (chiefly administrators) who may not be in sympathy or agreement with the focus on an environmental approach to education. These activities are intended to demonstrate that the cost and public relations aspect may serve to enhance such a program rather than hinder its development.

II Questions

1. Pose the following questions to the students to initiate or lead into a discussion relating to problems in those schools where a gulf exists between students, teachers, and administrators regarding the implementation of a viable environmental program.
   a. How might a small group of students communicate effectively with their principal, headmaster or similar administrator?
   b. What problems seem to underlie the difficulty? (cost public relations, scheduling)
   c. What angle of consideration of this particular aspect cited would be most effective in dealing with the specific problem?

d. How do you think that student action might help solve the problem and what limitations do you anticipate?

III Equipment

Materials for writing and illustrating should be available to the student as well as certain statistical data relevant to environmental education, books and newsworth articles which would assist the student in carrying out this type of activity.

IV Procedure

The method for seeking assistance and support from school administrators will vary depending upon the inherent problems of that institution and the type of environmental program desired by that school. Those students interested in specific aspects of pollution should be encouraged to take an active role in this activity.

Several procedural approaches are described below. One or more of them may be used as indicated by the problem in the school, perhaps combinations of two or more procedures may be used, or procedures not developed here but devised by the group to fit the particular situation.

1. Use of existing clubs, organizations or groups.

Make a check list of all the extra-curricular clubs and organizations in your school and select those groups which could be used to promote the cause of environmental education. Here are a few suggestions.

Art Clubs might be asked to sponsor a photography contest on pollution or pollution sculpture display in the school library. This would bring attention and interest.

Science or Biology Club might be asked to form a splinter group called the Ecology Action group which could actively campaign for the type of school program desired. The could distribute printed material on the merits of environmental education, generating further interest by use of bulletin board displays, posters, or conducting an all school assembly to "educate" all on the aims and goals of the specific program wanted at their school.

Debating Clubs might devote an entire school term to debating issues related to the pollution problem. School Publications would ideally serve as an effective instrument to disseminate information and keep the community up to date on progress of the "campaign". A special column on Environment in the newspaper, various pictures of worthwhile and pertinent activities accomplished by the school's participants could add much to the overall support of such an endeavor.

2. Large Group Activity

There is no better way to impress people of the significance of a particular need than the large group activity to improve or call attention to something.

Those students most interested or skilled in matters of organization might like to coordinate an all campus or all school Clean-Up. This would require committees to handle such areas as publicity, manpower, collection, sites, and disposal.

A Clean-up activity might be followed in a month or two by a beautification project undertaken by a smaller group or groups. The local newspaper could be called in to help the cause by a well placed feature article employing several pictures.

3. Improvisation of Equipment

Since the cost of any program is a main obstacle to overcome in the eyes of an administrator, those activities which show how experiments may be done at minimal expense are important. Students who are familiar with certain procedural techniques described in the guide should be asked to demonstrate how alternate methods may be used. Drawing from examples in the Bacteriology of Water section and the Hydrologic Cycle part, substitutions of more sophisticated equipment may be shown.

4. Public Relations

Many schools are concerned about their public image. The common practice of name calling and the subsequent loss of prestige make many an administrator hesitant about the school's direction in a full fledged program of environmental education.

Through the use of questionnaires, students may seek public information about certain issues relating to pollution. For example, sewage treatment in the school's area may be the topic for one questionnaire, or the district water supply may be another timely topic for polled opinion.

Radio programs and P.T.A. discussions by the students might be effective menas of large scale communication. The involvement of parents by means of a car pool for necessary transportation would bring in a very important interest group and at the same time provide them with an awareness of the sincere effort by the students in achieving their goals.

A very successful method of arousing public sentiment is the local newspaper. Students who have had journalistic experience should be encouraged to write weekly articles and document their news items with actual accounts of student activities at the school which are concerned with the environmental crisis.

V Past Activities:

1. Germantown Academy in Fort Washington, Pa.

Students at this school solicited certain business concerns in their community and asked for their help. Financial donations and specific equipment were given in many cases. For services which the students did, a cooperative arrangement was worked out whereby the industry was able to provide some service for the school. (ie. testing for DDT derivatives). In another instance, potato sacks were given for erosion control. Military surplus was solicited for possible useful materials and equipment.

2. The George School in Newtown, Pa.

   Students at George School have made a study of the Neshaminy Watershed, the results of the school year study were of great public interest in the region and copy of the results was sent to President Nixon. Response to the study from federal and state officials was great and such publicity would give impetus to any school program.

3. Mount Hermon and Northfield Schools in Massachusetts.

   Water quality parameters on the Connecticut River were studied in depth by several classes at these schools which received attention from the Conn. River Watershed Council and consequently they were asked to prepare a document for publication. One student working on an independent project made a thorough study of effects of biodegradable detergents on fish and other organisms. This brought widespread response from many companies and governmental offices. The value of these student oriented activities is obvious when seeking support from school administrators.

4. Quincy High School in Quincy, Mass.

   Innovating relevant curricula into the school system takes time, effort and special study. However at this public high school, teachers and students worked together in the design of an anthropology course which would include physical anthropology for half the course. Later a course on Environmental Studies was developed which was presented by the social science dept. and the science dept. employing a team approach to the teaching.

5. Douglas High School, Baltimore, Maryland.

   When some opposition to the implementation of an environment program in this school, the city science supervisor was invited to see the students at work on their selected projects. This approach has strong persuasuve power in convincing school officials.

   The student authored booklet, "A Study of the Gwynns Falls Stream" was distributed to interested teachers ad school administrators in their area.

VI Limitations

Perhaps the greatest obstacle to be encountered in attempting to impliment an environmental studies program is that of scheduling. Many schools are so regimented that it may be difficult for students and teachers to find the time needed for these activities. Since such a diversity of specific problems may arise here, it would be beyond the scope of this document to attempt a solution to all of them.

It may be possible to offer "time-trades" with other teachers. They may, for example, be much more willing to give up some of their lab or class time to you if you are willing to give up some of yours in return. It may be possible to convince athletic departments that an outside activity such as an all-school clean-up may be a worthy substitute for phys-ed classes one day. Such tactics as these are only beginnings, but as enthusiasm grows among the students, faculty, and administration, the possibilities are endless until finally the whole school may choose to revolve around an environmental theme.

One must also consider the possibility of alienating the local industrial polluters. This can be avoided if a positive rather than a negative approach to the problem of pollution is embarked upon. It is better to ask, "How can we work together to alleviate the problem"?, rather than trying to fight them directly. If tact is used, you may find that they are as interested as you are in working toward a solution and may even contribute in helping solve it. A strong word of caution might be given to those who are impulsive and impatient in their dealing with the public at large.

"Resolving in essence the quest of human survival and the quality of human life on a planet of fragile hospitality - this is an issue which must become of immediate concern to all segments of society." Ecotactics , Part VII.

VII Bibliography and Resources

C. I. Hovland, A.A. Lumsdaine, and F.D. Sheffield, Experiments on Mass Communication, Princeton University Press, 1949.

Hall, D.M. Dynamics of Group Action, The Interstate Printers & Publishers, Inc., Danville, Ill. 1964.

H.I. Abelson, Persuasion, New York: Springer Publish. Co. 1959.

Mann, John. Changing Human Behavior, Chapter 8, "Attitude Change Produced by Interpersonal Influence", Charles Scribner's Sons: New York, 1965.

Sierra Club Handbook for Environment Activists: Ecotactics John C. Mitchell and C. L. Stallings, Editors. (Pocket Books, New York, 1965).

The Hampshire Environmental Information Center (HEIC) in Cooperation with the Coalition for Environmental Quality (CEQ). University of Massachusetts, Amherst, Mass. 01002. (Campus Center Building). This Center is intended to provide the Northeast area with one centralized point for the collection and dissemination of

information related to environmental matters.

Phillips, Edwin A. Field Ecology, D. C. Heath & Co., Boston Mass. (A RSCS Lab Block for High Schools) 1965.

Hillcourt, William , Field Book of Nature Activities and Conservation, G.F. Putnam's Sons, New York, N.Y. 1961

J. Movie Making

I Introduction

Movie making is an innovative motivational teaching technique which can be successfully implimented to enhance student interest, learning, and creativity. A movie making project provides students with the opportunity to interact with peers and teachers to develop skills in the various areas involved in this type of activity, and to increase understanding of the subject being covered. With adequate planning a movie making project can be introduced at any level elementary through college. The complexity of the project depends on the age group involved.

II Questions

1. Elementary level - The movie making project should be an intergral part of a specified unit of study, with the purpose of making the unit of study more meaningful to the students.
    - a. How would you like to make a movie about ________?
    - b. What are some of the things we might have in our movie?
    - c. What are some things our movie should tell people?
    - d. What are some of the different jobs we will have to do to make the movie?

It might be feasible at this time to discuss the specific area or areas the film should include and a format of possible scenes.

2. High School level - The questions and discussions will be at a higher level of complexity.
    - a. What is the aim of the movie?
    - b. What effect is the movie trying to create?
    - c. What message is to be made by the film?
    - d. What equipment will be needed for the project?
    - e. What time limitations are involved?
    - f. Should we film all the facts (on the subject being covered), or just one?
    - g. Who is going to do the filming?

    The movie making project at the high school level provides an excellent opportunity for team work, as the students can become involved in the more refined areas of this type of activity.

III Equipment

1. Movie camera
2. Film
3. Light meter
4. Tripod
5. Editing equipment
6. Projector and screen
7. Lighting equipment

8. Notebooks

IV Procedure

1. Decide on suitable areas for film making activities.
2. Plan an intinerary that will provide as much sequence as possible.
3. Students should break into teams to work on various aspects of the movie. Students should be working in their interest area. Teams might be assigned some of the following activities:
   a. Care and cleaning of equipment.
   b. Arrange for lighting.
   c. Arrange for filming on private land (good public relations experience).
   d. Do the filming.
   e. Arrange for or do film development.
   f. Edit the film.

V Previous Studies

Several groups in the Water Pollution Program (WPP), Tilton School, New Hampshire, were successful in making suitable movies on water pollution. These can be obtained by contacting the program coordinator. The paragraph below was written after two days filming. A list of scenes filmed also appears.

The purpose of this movie is to follow a river from its headwaters to the Atlantic Ocean, showing the effects of human activities on the river. As we started to do this, we noticed we could divide the river into three parts. The first part is the headwaters of the Fowler River which flows from Mt. Cardigen to Newfound Lake. In this section there is no human activities to effect the river. At Newfound Lake, the first influences of human activities are noticed as the Lake is widely used for recreation. At this point the second phase of the movie starts. The outlet of Newfound Lake runs into the Pemigewaset River a few miles down stream. The Pemigewaset, polluted at this point, runs through Bristol to Franklin, where it meets the Winnipesaukee River and becomes the Merrimack River. The second stretch ends up with the Merrimack flowing to Concord. Along this stretch we see the introduction of human activities which will later increase. The third stretch follows the Merrimack from Concord through all the towns along the river, until it empties out into the Atlantic Ocean. Along this part of the river we observe the effects of heavy human activity upon the river. To give a better picture of what we wish to portray, we will be using one movie and two-slide porjectors running at timed intervals with the movie projector.

Slides The slides will be taken so as to show the area around where the scene was shot. It will be used as a transition element, pulling some of the scenes together. Ideally like Jerry Garcias guitar.

Scenes That Have Been Shot

Scene 1. Sunrise on Mr. Cardigan. Shot at two frames per second. The first 30 seconds will be seen without slides as the sun jumps up. Time, 90 seconds

Scene 2. Water dripping from a rock. This shows the water as it first seeps down the rocks. Time, 45 seconds

Scene 3. Water pool. Shot from just below scene 2 Time, 15 seconds

Scene 4. Moss and Stream. The stream joins with another. Time, 26 seconds

Scene 5. Water bugs in pool. Used zoom to capture bugs. Time, 20 seconds

Scene 6. Waterfall Time, 20 seconds

Scene 7. Bullfrog and bubbles. Just below falls. Time, 15 seconds

Scene 8. Welton Falls trail. First shot on the Fowler River. This stream is much larger than those in the previous scenes. The slides will serve as a transition. Time, 15 seconds

Scene 9. Small waterfalls along Fowler. Time, 25 seconds

Scene 10. From bridge to Fowler. As in scene 8 their is a great jump in the size of the stream. So slides will be used as a transition.	Time, 15 seconds
Scene 11. From Lichen to suds. Focus through lichen to suds.	Time, 11 seconds
Scene 12. Spider Web	Time, 20 seconds

The scenes listed above were shot for part 1. Those that follow are for part 3.

Scene 1. Pan bridge to boats off pier. Newburyport.	Time, 20 seconds
Scene 2. Boats in bay off pier. New buryport.	Time, 15 seconds
Scene 3. Shooting toward Plum Island. Newburyport.	Time, 15 seconds
Scene 4. Below Rt. 495 bridge of river and trees at Haverhill.	Time, 15 seconds
Scene 5. At Lawerence, looking upstream from bridge on south side.	Time, 15 seconds
Scene 6. At Lawerence, effluent and steam pipes taken from bridge.	Time, 15 seconds
Scene 7. At Lawerence, effluent pipe taken from bridge.	Time, 15 seconds

Scene 8. Looking upstream from bridge on the north side. Time, 15 seconds

Scene 9. At Lawerence, looking downstream from bridge on north side. Time, 15 seconds

In a communications class, some juniors in high school made movies as a substitute for term papers. In a high school science class, students made a documentary movie on pollution and the environment .

We have found in our experiences that one must focus on a scene for at least 12 seconds, as it takes a viewer that long to comprehend and enjoy the scene.

VI Limitations

In some schools the cost of the equipment may be prohibitive. Thorough investigation of various sources though indicate that some companies are quite willing to donate necessary equipment. The local camera store might be a possible consideration.

Students using the equipment should be carefully versed in its operation.

VII Bibliography

Monier, P., The Complete Techniques of Making a Film. Amphoto, New York.

A book written in the language that one who has never picked up a camera can understand. This book can be

used by junior high school students and older.

Hughes, Robert, Film Book I, the Audience and the Filmmaker, Grove Press Inc., New York 1959

A book for both teacher and student. It is "concerned with the situation of the serious filmmaker - how he works and what he is up against." The chapter which presents an interview with Fellini was most exciting.

Peters, J.M.L., Teaching and the Film, International Documents Service, 1966.

A book on the techniques of film making, which can be used by high school students.

K. Making Film Loops

I Introduction:

The film loop has been proven to be a good way of stimuating interest and discussion on any topic. Loops are 5 minutes long, usually they are used to trigger the interest of the viewer. If the student participates in the making of one of these on the water pollution problem, he is able to transmit his feelings to others by another communication media.

II Questions:

1. To lead into the activity as students:
   a. Are the movies and other audiovisual aids that we have representative of this locality?
   b. Can you relate to them?
   c. What do you think would make a better presentation?
   d. Where do you think we should go to make a film loop?
2. To initiate activity ask students:
   a. Who would like to try to make a film loop?
   b. What do you think will make this an effective film loop?
3. To continue the activity ask students:
   a. How could this benefit other persons in our community?
   b. What can we do to make this available to other people?
4. To evaluate the students performance consider such questions as:

a. Did everyone contribute to this activity?

b. Is the loop representative of the community's pollution problem?

c. Is this loop representative of the pupils' concept of the pollution problem?

III Equipment

1. Super 8mm or 8mm Movie camera
2. Film
3. Light Meter (if necessary0
4. Tripod (if necessary)
5. Editing equipment
6. Film loop projector and screen
7. Flood lights (if necessary)

Some companies will donate equipment or money to schools that are planning to have the students make movies.

IV Procedure

1. Make a survey of your community to find suitable areas.
2. Plan an itinerary that will provide as much sequence as possible.
3. Make a definite plan and format for making the film loop.
4. Edit your movie.

Have a loop made of the edited movie (send it out for loading).

6. Add sound track if desired.

V Previous Studies

At Germantown Academy Biology 1 and 2 students did loops to demonstrate standard methods in biology laboratory techniques. These loops are now used by the students to prepare for lab.

VI Limitations

1. Photographic equipment of good quality should be available.
2. The cost of the materials that are needed for this activity may be prohibitive for some situations.
3. Individuals undertaking this project should have an adequate knowledge of the problem areas in the community.
4. There should be a thorough understanding of the limitations of camera that is to be used for this project.

VIII Bibliography

Monier, P., The Complete Techniques of Making a Film, Amphoto, New York. A book written in the language that one who has never picked up a camera can understand. This book can be used by junior high school students and older.

Hughes, Robert, Film Book I, The Audience and the Filmmaker. Grove Press Inc., New York 1959. A book for both teacher and student. It is "concerned with the situation of the serious filmmaker - how he works and what he is up against". The chapter which presents an interview with Fellini was most exciting.

Peters, J.M.L., Teaching and the Film. International Documents

Service, 1966. A book on the techniques of film making, which can be used by High School students.

L. Non- Returnable Containers

I. Introduction

This activity allows students to identify and react effectively to the problem of bio-non-degradeable containers. Basic questions are provided; however it is projected that questions will be posed by students that will require considerable class discussion. This activity may be carried out by junior and senior high students.

II Questions

1. To lead to the activity ask:
   a. What varieties of non-returnable containers are produced?
   b. What disposal methods are used by private and public communities?
   c. Does disposal present a problem? (If so specify)
2. Initiate the activity by asking:
   a. How can our concern for this problem be channeled?
   b. Is an advertising campaign the method to follow?
   c. Can our aid help mitigate the problem?
3. Continue the activity with:
   a. What public agencies and companies should be contacted for information?
   b. Is it plausible to appeal to the public through small projects under the auspices of various organizations such as the school?

c. In what manner can the greates success be achieved?

4. Evaluate the students by considering:

   a. Is success for this type of project possible on a large scale?

   b. Has personal involvement increased?

   c. Has community concern and cooperation increased at all?

III Equipment

1. Trash cans filled with various types of non-returnable containers.
2. Photos of dumps or other areas used for the deposit of these containers.
3. Maps and data for recording survey.

IV Procedure

1. Large group opening of class.....teacher will utilize the discussion questions from Part II and/or provide articles for the students to read and evaluate in small groups and report on to the large group. (Articles identifying the problem posed with bio-nondegradeable containers).
2. The teacher will invite the students to form their own groupings to evaluate the problem of bio-nondegradeables in their community. Areas for investigation might include Pathways for container wastes; compilation of material examples of bio-nondegradeables (BND); What companies make, sell, and service BND containers for our community?; An overview on the recycling of BND materials.

3. Small group activity to plan approaches to the various offenders in order to communicate directly with them and discuss from the standpoint of either recycling or non-production ways to correct the problem.

V Past Studies

A group of students at Germantown Academy became aware of the possibilities of re-cycling and started a chain letter to others urging a boycott of non-returnable beverage containers. They also prepared a model legislative package for use on a state level.

VI Limitations

1. The students must be encouraged continually to make their investigations seriously, particularly when approaching businesses and manufacturers.
2. It is important for the student to value what he is investigating. The investigation should be of the students own volition and the teacher must allow for individual differences in approach to the issue.
3. The students must not be led into thinking change will occur overnight; however, should, on the other hand be encouraged to be persistant in his efforts and thorough in his follow-up.

VII Bibliography

Periodicals nowadays feature bio-nondegradables frequently.

If a file is begun on the subject by clipping newspapers and weekly news journals, a supply of information will develop quite quickly.

M. Anti-Pollution Art

I Introduction

This activity gives students a chance to express their personal attitudes towards pollution through creative art forms. Students will become more aware of the environmental crisis, and through their art, pass this awareness on to others. This activity can be used with any age group, and requires no background or artistic ability.

II Questions

1. To lead into the activity, ask some questions similar to the following:
   a. How can we communicate our concern about the pollution problem to others?
   b. Could posters, collages, and other art forms be useful in communicating this concern?
2. To actually start the activity, ask:
   a. What materials could be used in making this art?
   b. Should we run an anti-pollution art contest?
3. To continue the activity, ask questions like:
   a. Should we use slogans, humor, and cliches in our posters?
   b. If we run a contest, who will be involved? Just the class, one grade, the entire school, the whole community?
   c. Should there be a prize as incentive for this contest?

4. To evaluate the students' efforts:
   a. Who is doing the activity, and with how much interest and enthusiasm is he going about it?
   b. How well has each student planned his project?
   c. Are the participants working?

III Equipment

1. Litter (have the students collect this themselves)
2. Glue
3. Magic Markers
4. Poster Paper
5. Paints and Brushes (Note: if posters are to be displayed outdoors, be sure to use weatherproof paing)
6. Lots of enthusiasm and imagination!

IV Procedure

1. Be enthusiastic and interested about this project and your students will be too. Start off by taking your class to
2. the scene of actual pollution: a nearby river, pond, beach, etc. Have them observe the pollution and react to it, then start collecting the trash, some of which may be used in the actual making of their art projects.
2. Plan the project and collect any additional materials to be used in individual projects.
3. Begin to create an expression of your attitudes about pollution, using unique materials and ideas.

V Previous Studies

1. One school recently held an environmental art contest for Earth Day (1970) in which not only posters and collages were entered, but also an assortment of oddities ranging from mobiles to a piece of artwork made using an old toilet. The contest was judged by certain faculty and student members of the Environmental Pollution class at the school, and prizes consisted of humorous, yet anti-pollution type gifts, such as waste paper baskets and fly swatters (instead of DDT)!
2. The team from Beta group, Tilton School, N.H. decided that the items of metal trash were heavy enough to require welding to attach pieces. Items were taken to a shop where welding is done. Some of the collection we had to work with resembled parts of animals and plants to us. Pieces were spread out on the floor and arranged and rearranged by trial and error. We adopted the theme that pollution is killing our natural flora and fauna, so in the future man might only be able to enjoy synthetic plants and animals made from these pollutants.

   We produced a crane or heron type bird, a cat tail, a turtle, and a skull and cross bones. We made a sign by bending wire to form the words: pollution era -- flora and fauna. These we stapled to a plank with a tacker stapler and balanced the sign on another item from the collection.

VI Limitations

1. Few posters may be produced if students are not enthusiastic and the activity not publicized enough.
2. Posters placed outdoors may run and become weather-beaten.
3. If a contest is held, it could last too long.
4. Teachers should allow students ample time to plan and work on their projects.
5. A contest with prizes would probably be more suitable for younger students (up throug jr. high?) then for high school and up.
6. Heavy metal items may require welding, but are worth examining for other methods of joining. Welding could be done in the school maintenance shop, the vocational education shop or any privately owned shop where the operator can be interested in helping the group with the project.
7. Cast iron pieces are difficult and costly to weld to steel pieces.

VII Bibliography

Creative Paper Design by Ernst Rottger Reinhold Book Corporation, New York, 1968.

Lynch, John. How To Make Collages, Viking, 1961

Therese Schwartz. Plastic Sculpture and Collage, Hearthside, 1969.

Mary Seyd, Designing with String, Batsford, 1967.

N. Model Making

I Introduction

This activity interests the students in making models of buildings, plants, and equpiment. In this project, for all grades, it is intended that the students will do research on models thus learning about the control of pollution.

II Questions

1. Lead to the Activity by asking: what buildings or equipment can be found that help control pollution.
2. Initiate the activity with:
   a. How could you build a model of this kind?
   b. What materials could you use to make this?
   c. Would you make an actual working model or a cardboard one?
3. Continue the Activity with:
   a. How would you make it work if you made a working model?
   b. What would a model like this show people who don't know about sewage plants, buildings, and equipment?
4. To evaluate, ask:
   a. Is the model well constructed for the time alotted?
   b. If it is a working model, does it work correctly?
   c. Does the student know how it works; could he explain

the process?

d. Does the student feel he has gained an understanding of why we have such plants?

III Equipment

1. Working Model
    - a. Cement Mixture
    - b. Sand, Rocks, etc.
    - c. Motor to run mixing device
    - d. Airaition device
    - e. Settling tank
    - f. Glass tubing
    - g. Possibly glue
    - h. Paint
    - i. Labels
2. Non-working Model
    - a. Card-board and boxes
    - b. Paint
    - c. Glue
    - d. Glass tubing
    - e. Wood splints
    - f. Pins
    - g. Settling Basin (small washing basin)
    - i. Sand and gravel
    - j. Labels

IV Procedure

1. Make or get a blue print of your idea.
2. Do research as to how it works and what it is constructed of.
3. Construct the model.
4. Paint any parts that are necessary.
5. Label parts

V Previous Studies

Models often serve as the best illustration of things to large to see all at once. At Germantown Academy two topographical maps (approximately 32 x 8 feet each), are under construction to show the entire Wissahickon Valley watershed and the school campus. The models when completed will be mounted on the side walls of the science lecture hall. Several overlays will be used to illustrate, biological, bacteriological, chemical, social and political aspects of the watershed.

VI Limitations

1. Materials may be hard to work with
2. Glue may be hard to work with (watery, not flowing, etc.)
3. Time may be too short
4. Small models take a long time to filter materials, thus patience is needed.

5. Projects may leak.

VII Bibliography

"Aquarius...New Concept in Water Treatment", Neptine Micro Floc Inc., Neptune Meter Co., Oregon

Goodman, Brian, Package Plant Criteria Development, National Sanitation Foundation, Michigan, 1966

Municipal Sewage Treatment Processes, U.S. Department of HEW.

Sewer and Sewage Treatment Plant Construction Cost Index, FWPCA Division of construction Grants, Washington D.C.

"Custom Coagulation Control of Water Treatment",

O. Student Planning of a Pollution Assembly

I Introduction

This activity is designed to motivate students to plan a slide show on their local pollution problems to be shown at a school assembly. Such an assembly might act as a springboard to further activities on a larger scale if it is successful in bringing an awareness of local conditions to the student body. An assembly of this kind can be planned and produced by students at any level. Since it is possible to classify pollution into four categories: air, water, sight and sound, with minor variations this activity could be done with a tape recorder concentrating on sound pollution.

II Questions

1. Lead to the activity by asking:
    a. Is the student body as a whole aware of our local pollution problems?
    b. What might we do to make them aware?
    c. Does merely telling them about pollution have as great an effect as showing it to them?
    d. Would a slide show, showing pollution in our city, town, be interesting to the students?
2. Questions which initiate the activity:
    a. Which sights in our area are particularly offensive to sight?

   b. What pictures would really have an effect on the students in our school?
   c. Have any areas become polluted recently so that they might remember them as they were before!
   d. Are there any areas of potential natural beauty which have been spoiled by pollution?

3. Questions which continue the activity:
   a. Should we focus it on one sight, showing it from many angles, times of the day, etc. or should we expand to cover many sights in the area?
   b. Are there rivers that become more polluted as you pioneered downstream so that you could show a progression from beauty to pollution?
   c. Should we have a sound track to accompany the slides?
   d. Should we break up into groups in order to produce the show, ie editors, directors, photographers, sound coordinator, projection man, tape or record technichian, etc.

4. Questions which help the teacher evaluate the students' efforts:
   a. Does the student try to produce a show which will have an effect on others or is he merely doing what he thinks is interesting? (Of course he could be

doing both successfully.)

b. How did the students and teachers in the audience react?

c. Did any long term projects result from the assembly?

d. Were these or other students motivated to become involved in further assembly programs in the school?

III Equipment

cameras, projector and screen, tape recorder or record player (if a sound track will accompany slides)

IV Procedure

1. The organization should all be accomplished in the classroom. The activity can be accomplished in two ways depending on your circumstances. A class field trip approach may be utilized to take the pictures or students may be organized to take the pictures on their own time after school.
2. The students should agree on the total impact they wish to create on the audience and consciously strive for it. Most of this will occur during editing and arranging of the slides and coordinating of sound.
3. Sufficient time must be allowed for the slides to be developed and returned.
4. A date must be arranged for the assembly so that the students have a goal and real purpose to work towards.

5. After slides are obtained the real work begins. They must be arranged and edited to create the desired effect. It may sometimes even be necessary to cut out good slides if there is an over abundance; one or two slides of certain scenes are sometimes more shocking than a dozen. The level of sophistication in coordinating sound and slides will varry according to availiable equipment and the students talents, however, they should be aware that the two do interact with each other and if used carefully can become a real asset to the production.
6. There may or may not be any introduction or narration, depending again on the total effect desired by the students.

V Past Studies

Young people seem to enjoy nothing more than working with cameras these days and the results of their efforts are often surprising. A group of students at Tilton School produced a film and slide show titled "the river" which they eventually showed to the participants of the water pollution program and plan to enter in an amateur film contest.

These students took about a week to complete filming. They began with a spring at the top of Cardigan mountain in N.H. and followed the path it took to reach the Atlantic Ocean.

The beginning slides included beautiful pastoral scenes, but these soon gave way to scenes of extreme pollution. As the spring became a stream and the stream a river, it passed the Franconia Paper Mill, which in 1954 contributed 96% of the pollution in the Pemigewasset River. Moving through Franklin, N.H. the Pemigewasset becomes the Marrimack River and the students continued taking scenes of pollution in Concord, Manchester and on into Massachuttes.

After the picture taking was finished and the slides had returned edited and added sound with a tape recorder. (Later this became a multi-media show and the students added a motion picture film in the center, showing their slides on both side of it.)

VI Limitations

Most schools are equiped with slide projectors as well as tape recorders or record players. Many new make cameras availiable or, if not, either the teacher, the students, or their parents can usually make one or several available for use. The class may decide to share the cost of having the slides developed or the school may have money available for this purpose. If more of the above is true, try asking the local camera store to lend you a camera and necessary equipment. In short, equipment is not a limitation.

However, some problems may be encountered in travel if the sights chosen are not within walking distance. The problems here depend on the size of the class, or at least of the group actually doing the photography. Car pools might be organized among the parents and the group can be broken down into smaller units. Perhaps units could be in charge of Photographying one sight each thus writing down the total number who must visit each sight.

VII Bibliography and Resources

Boucher, Paul Edward, The Fundamentals of Photography, 3rd edition, Van Nostrand, Pub., N.Y., New York. (1955)

A good book for the fundamentals of working a camera, also available in 4th edition. 1963

Blaker, Alfred A., Photography for Scientific Publication, W.H. Freeman and Co., San Francisco, Calif. (1965)

Especially good for techinques on small objects, insects, etc.

There are many good books on the fundamentals of photography--your selection need only take into account the level of sophistication of your equipment.

P. Role Playing

I Introduction

This activity is designrd to familiarize students of seventh grade level and up with the function of local goverment and how they can take part in a town's decision making process. The setting is the local Town Hall where a special metting has been called to consider the proposal that motor boating be banned on a nearby lake.

II Questions

1. To lead into the activity, ask questions similar to:
   a. What type of people would you expect to find present at a local town meeting on this issue?
2. To initiate and continue the activity, ask:
   a. Why would these people act and think as they do?
   b. Where could you find information on each character role?
   c. Which character would you like to be? (followed by character assignments).
3. To continue the activity ask the students why they are playing the roles the way they are.
4. To evaluate the activity ask the students to write a reaction paper. Note whether they really understand what was going on. Recapitulate the activity with the students to assure that they followed the development.

If a tape recording has been made this will be helpful. If more than one class has been recorded, play the tapes so that the classes may compare their activities.

III Equipment

Use a tape recorder, if desired.

IV Procedure

Students are asked to imagine what various special interest actions could be expected to be in attendance at the town meeting and what statistics and facts these people might use to support their position.

Students are encouraged to identify with one of these factions by imagining themselves in this role for a few days prior to the actual meeting. See past studies in Section V.

A Few Tips On Parliamentary Procedure

1. Always wait until the moderator has recognized you before you begin to take the floor.
2. Always stand when speaking.
3. Always be courteous as you present your argument. Do not state opinions without being able to draw examples and give proof. Be accurate about dates and statistics.
4. Do not ask a question directly to or speak to other members in the audience...always put such matters through the chair.
5. If you propose an amendment to the article in question, don't forget that the amendment must be prepared as a

motion - seconded and then voted upon separately before going to the original question for ratification.

6. Address the moderator as Mr. Chairman or Mr. Moderator.
7. If there are many people tring to be recognized at the same time, you must stand and wait until you have an opportunity to speak.
8. You may through the chair ask for an opinion from any of the local town officials, ie., town counsel - attorney, local board of health official, local planning board official, town engineer.

V Past Studies

Procedures outlined in section IV were carried out. Discussion of the motor boating ban article was lively and enjoyable and lasted for one hour and fifteen minutes. Suggested characters which were used in this particular role play were:

1. Junior Chamber of Commerce president or member: enthusiastic about the possibliities for making money on tourist trade in the area. Feels that preventing people from using powered craft at the lake will cause people who plan to develop property around this region into motels, ice cream stands, hamburger stands and other franchises to lose the money they invested.
2. Members of a rapidly organized group who call themselves The Lake Boat Owners and Water Skiiers Federation (Sports

loving Pepsi generation types).

3. Local members of real estate and brokerage firms. Feel they are being discriminated against and claim that they are concerned that people from cities would be, in effect, discriminated against.
4. A representative from your school. (pick your own character).
5. A pritate lot and boat owner who has recently gotten permission through the planning board to build a cottage on the lake. He feels that such a ruling would be unfair to him since he assumed that when he invested the majority of his life savings in this recreational area that there would be no restrictions on his recreation activities.
6. An old resident basically fed up with newcomers entruding more and more into what had been to him, an area of peace and tranquility for as long as he can remember.
7. A poorly motivated individual who is a rather shady character and has a personal financial interest in selling a product which he claims will eliminate oil scum.
8. Local representative of the John Birch Society who see this bill as another example of unnecessary social control which is detremenal to the American traditional concept of personal freedom.
9. Representative of local Conservation Committee who wishes to preserve the natural beauty and environmental quality

of the area.

10. Moderator of the town meeting.

Participants found useful in their role participation, the brief guide to parliamentary procedure which is included in the procedure section.

VI Limitations

1. If students have no experience in role playing or parliamentary discussion it may be useful to spend 10 minutes in a dry run dealing with the suggested issue.
2. Choose a student with a rather forceful personality for the moderator.
3. Students must have the time to obtain a thorough knowledge of their role and how it relates to the issue in order to guarantee enthusiastic participation.

VII Bibliography

If possible, select games the students are familiar with and use the rule books as a basis of discussion.

This appendix is included as a technical reference aid to teachers using this guide. It is organized in four parts: (A) Chemistry, (B) Bacteriology, (C) Aquatic Biology, and (D)Engineering and Physics.

A Chemistry

Chemical parameters are quite specific, can be quantitated relatively quickly and precisely and can be related to water quality requirements. It is seldom feasible or worthwhile to apply all analytical procedures to a given water sample. However, certain analyses are performed more or less routinely on water samples and are included in this section.

Each part includes an identification of the selected parameter and its common sources. This is followed by a description of the chemistry involved in the more common approaches to the analysis of that parameter. The procedures include references to commercial testing kits and, in some instances, detailed instructions for those who do not have access to commercial kits.

Commercial kits provide effective approaches to rapid and reasonably accurate analyses, especially when time, facilities and lack of trained personnel are limiting factors. Consequently, the procedures include references to the following commercial units:

Delta Model 50 Portable Laboratory, Delta Scientific Corp.

Lindenhurst, N.Y. 11757.

Hach DR-EL Portable Engineer's Laboratory, Hach Chemical Co., Ames, Iowa, 50010.

LaMotte Model #AM-21, LaMotte Chemical Products, Co., Chestertown, Maryland, 21620.

These kits have been identified only because they proved satisfactory during the development of this program. This endorsement does not imply superiority to other units that may be commercially available.

An annotated bibliography appears at the end of this section. The listings include those references which should be readily available when investigating chemical parameters of pollution.

1. Acid-Base Parameters

a. Acidity

Acidity, a measure of the ability of a water sample to neutralize hydroxide (OH^-) ions, is subdivided into free (mineral), unionized (weak acid) and total forms. The chemical species which neutralizes the hydroxide ion is identified as the hydrogen ($H+$) ion and is present in all water samples.

Some of the substances which contribute to acidity, i.e., serve as sources of hydrogen ions, are depicted in Fig. 1. Direct hydrogen ion donors are depicted within the circle while those outside the circle provide hydrogen ions directly.

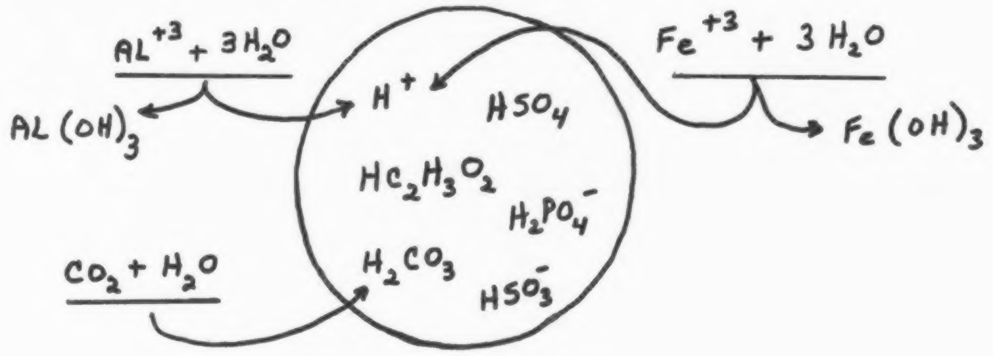

$Al^{+3} + 3H_2O$
$Al(OH)_3$
H^+
HSO_4
$HC_2H_3O_2$
$H_2PO_4^-$
H_2CO_3
HSO_3^-
$CO_2 + H_2O$
$Fe^{+3} + 3H_2O$
$Fe(OH)_3$

Fig. 1 - Total Acidity

1) Free Acidity

All acids contain hydrogen; however, certain acid compounds readily dissociate to form H^+ ions in water solution.[1] This dissociated (free) form of the hydrogen ion is known as free acid (Fig. 2) and is a component of industrial wastes and drainage from sulfide-rich terrain.

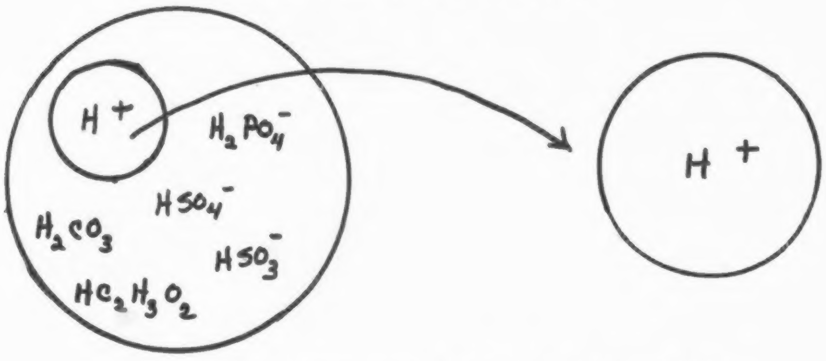

H^+
$H_2PO_4^-$
HSO_4^-
H_2CO_3
HSO_3^-
$HC_2H_3O_2$
H^+

Fig. 2 - Free Acidity vs. Total Acidity

---

[1] The H^+ is bound with water in forms such as H_3O^+ but will be considered as H^+ throughout this guide.

When hydroxide ions are added to an acidic water sample they react with the free acid to form water, thus resulting in a decrease in the free acidity (Fig. 3). The quantity of hydroxide ions needed to reach the methyl orange end-point is considered a measure of free acidity.

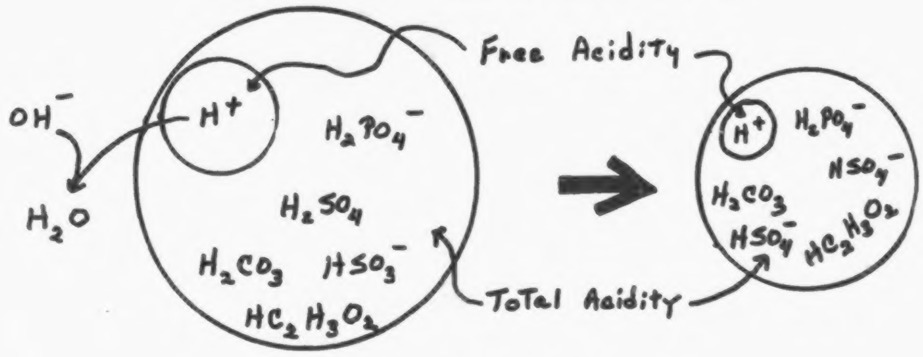

OH^-
H_2O
H^+
$H_2PO_4^-$
H_2SO_4
H_2CO_3
HSO_3^-
$HC_2H_3O_2$
Free Acidity
Total Acidity
H^+
$H_2PO_4^-$
HSO_4^-
H_2CO_3
HSO_4^-
$HC_2H_3O_2$

Fig. 3 - Free Acid Titration

a) Procedure

(1) The Hach and LaMotte kits do not provide instructions for free acidity determinations. However, it is possible to extend their CO_2 procedures to include free acidity measurements by titrating to a methyl orange endpoint before going on the the phenolphthalein endpoint as follows:

1. Prepare the sample as described in Step 1 of the kit procedures.
2. Add 1 drop of methyl orange indicator

(see (3) below). If the solution is orange-yellow, the free acidity is not measurable. Continue with step 2 of the kit procedure if a Bound acidity value is desired.

3. Titrate with the titration reagent designated for the kit's CO_2 procedure until the orange-yellow endpoint is obtained. If chlorine residuals interfere with the endpoint determination add 1 drop 0.IM sodium thiosulfate to a new sample and repeat stages 2. and 3.
4. Record the volume of titrant used and calculate the free acidity in the same manner as described for the CO_2 procedure. Both kits use sodium hydroxide as the titrant according to the following reaction:

   $Na^+ + OH^- + H^+ + X^- = Na^+ + X^- + H_2O$

   (X^- = any anion of a titrateable acid)

(2) The Delta kit has a free acidity procedure which utilizes the reaction just described, but substitutes brom cresol green indicator for methyl orange. It is also possible to adapt the Delta CO_2 procedure to a free acidity determination

as described in (1).

(3) An alternate procedure (1) is available as follows:

Equipment:

25 ml graduated cylinder

medicine droppers

50 ml Erlenmeyer flask

buret of 1 ml pipet graduated in 0.1 ml units.

Reagents:

Methyl Orange Indicator: Dissolve 0.5 g methyl orange in 1 liter of distilled water.

0.1 M Sodium Thiosulfate: Dissolve 2.5 g $Na_2S_2O_3 \cdot 5\ H_2O$ in 100 ml of distilled water.

0.02 M NaOH: Prepare 1 M NaOH by dissolving 4 g NaOH in 100 ml of FRESHLY BOILED distilled water. Then dilute 2 ml of the stock solution to a 100 ml volume with FRESHLY BOILED distilled water.

Procedure:

1. Measure 10 ml of sample into the 50 ml Erlenmeyer flask.
2. Add 1 drop of Methyl Orange Indicator. If the solution is orange-yellow, the free acidity is not measurable and should be

reported accordingly.

3. Titrate the sample with .02 M NaOH. Record the ml needed to reach the orange endpoint. If chlorine residuals interfere with the endpoint determination add 1 drop 0.1M sodium thiosulfate to a new sample and repeat stages 2. and 3. (A reference for the endpoint can be prepared by adding 1 drop of methyl orange to 10 ml of pH 4.5 solution prepared by combining 1.36 g $C_2H_3O_2Na \cdot 3H_2O$, sodium acetate, and 10 ml 1 M $HC_2H_3O_2$ with water to make 100 ml solution.)

Calculations:

For uniformity, acidity is expressed as $CaCO_3$ equivalents even though no $CaCO_3$ may be present. The equation for calculating free acidity is

$$\text{Mg } CaCO_3/l = \frac{(A)\ (\text{Molarity of NaOH})}{\text{Sample Volume}} \cdot 50{,}000$$

If: Molarity of NaOH = 0.02 M

Sample Volume = 10 ml

A = ml of 0.02 M NaOH needed to attain the methyl orange endpoint,

Then: Mg $CaCO_3/l$ = A x 100

(2) Unionized (Bound) Acidity (CO_2 determination)

The acids in the larger circle of Fig. 2 account for unionized acidity. However, CO_2 is primary contributor to unionized acid levels in most samples ($H_2O + CO_2 = H_2CO_3$). Carbon dioxide commonly enters water via absorption from the atmosphere and as an end-product of both aerobic and anaerobic biological oxidation.

Once the free acidity is decreased sufficiently by reaction with hydroxide ions, weak acids such as carbonic acid begin to release their hydrogen as free hydrogen ions (Fig. 4).

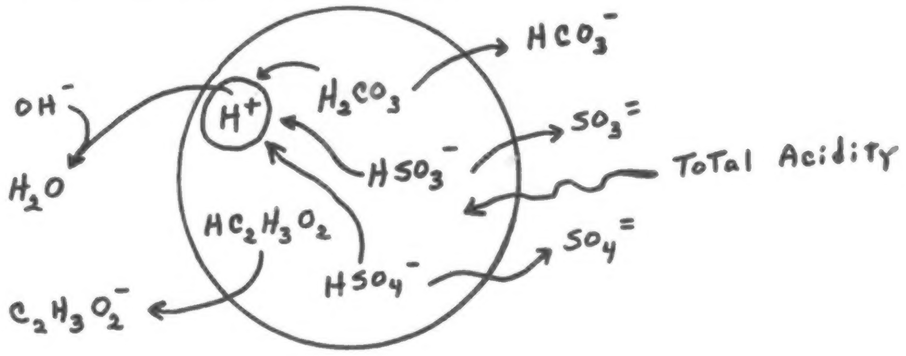


Fig. 4 - Weak Acid Titration

When enough hydroxide ions are added to reach the phenolphthalein endpoint, these substances will yield most of their bound hydrogen. Consequently, a quantitative evaluation of unionized acidity is achieved by calculating the amount of hydroxide added.

(a) Procedure

(1) The Hach, Lamotte and Delta procedures are actually evaluations of total acidity (free and unionized). The free acidity in water which has a pH greater than 4.5 is not measurable. However, if the pH is less than 4.5, free acidity determinations must be completed and then subtracted from the total value obtained by means of this procedure. The reactions are:

$$2\ NaOH + H_2CO_3 = 2H_2O + Na_2CO_c \qquad (1)$$

$$H_2O + Na_2CO_3 + CO_2 = 2\ NaHCO_3 \qquad (2)$$

Reactions (1) and (2) are employed if NaOH is the titrant. Only Reaction (2) is employed if Na_2CO_3 is the titrant.

(2) The following procedure is suggested as an alternate.

Equipment: See (3) under Free Acidity.

Reagents: Phenolphthalein Indicator: Place 0.5 g phenolphthalein in 50 ml ethanol and dilute to 100 ml with distilled water.

0.1 M Sodium thiosulfate: Refer to Free Acidity, part (3).

0.02 M NaOH: Refer to Free Acidity, part (3).

Procedure:

1. Measure 10 ml of the sample into the 50 ml Erlenmeyer flask.
2. Add one drop of phenolphthalein indicator. (If the solution turns pink, there is no measurable acidity.) Titrate with 0.02 M NaOH until the pink phenolphthalein endpoint is reached.

Calculations:

Acidity is expressed as mg/l $CaCO_3$. The unionized fraction may be calculated according to the following equation:

$$\text{Mg } CaCO_3/l = \frac{(B)\ (\text{Molarity of NaOH})}{\text{Sample Volume}} \cdot 50{,}000$$

If: Molarity of NaOH = 0.02 M

Sample Volume = 10 ml

B = ml of 0.02 M NaOH needed to attain the phenolphthalein endpoint after completing the methyl orange titration

Then: Mg $CaCO_3/l$ = B x 100

(3) Total Acidity

Total acidity includes all hydrogen ion donors measured by titration of a water sample to the phenolphthalein endpoint.

(a) Procedure:

(1) The CO_2 procedures in the Delta, Hach and LaMotte kits will give total acidity evaluations without modification.

(2) An alternate approach is to combine the alternate procedures suggested for free unionized acidity as follows.

1. Titrate to the methyl orange endpoint and calculate free acidity if desired (see (1)).
2. Add phenolphthalein and titrate to the phenolphthalein endpoint. (See (2)) Calculate the total acidity as mg/l $CaCO_3$ according to the formula Mg $CaCO_3$/1 = C x 100, where "C" = total volume of titrant used.

(4) Reference:

1. Standard methods for the Examination of Water and Wastewater, American Public Health Association, 12th Edition, New York, pp. 46-47, (1965).

b. Alkalinity

Alkalinity is an indicator of the ability of a given water sample to neutralize or accept hydrogen (H^+) ions. Some of the substances which comprise or contribute to alkalinity within the pH range of 4.5 to 11 are depicted in Fig. 1.

The circle on the left of Fig. 1 includes several substances which accept hydrogen ions directly during alkalinity measurements (titrateable alkalinity). The circle on the right includes substance which undergo chemical changes such as the hydrolysis of water which produce hydrogen ion acceptors. Those chemical species within the overlap of the two circles may serve in both capacities. Hydroxide, carbonate, and bicarbonate ions are normally the predominating members of their respective groups.

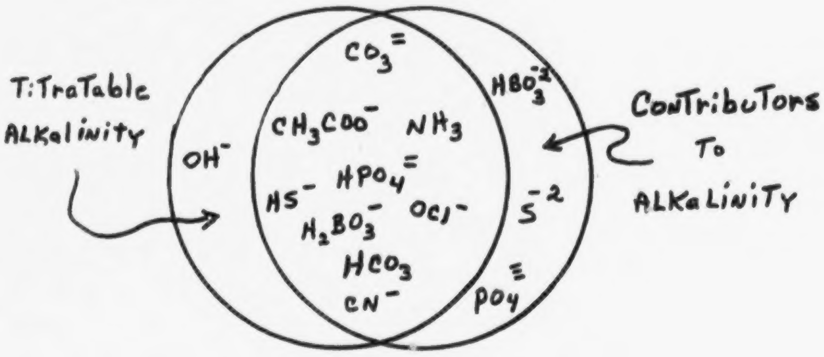

T:TraTable ALKalinity
OH⁻
$CO_3^=$
CH_3COO^-
NH_3
$HPO_4^=$
HS^-
$H_2BO_3^-$
OCl^-
HCO_3
CN^-
HBO_3^{-2}
S^{-2}
$PO_4^{\equiv}$
ConTribuTors To ALKaLiniTy

Fig. 1 - Components of Alkalinity
(pH 4.5 to 11)

Alkalinity is determined by titrating samples which are alkaline to phenolphthalein to the phenolphthalein endpoint with sulfuric acid. This serves as a measure of the "phenolphthalein alkalinity" which includes nearly all hydroxides and half of the carbonates present. Titration is then continued beyond the phenolphthalein endpoint to the methyl orange or brom cresol green/methyl orange. This step of the titration neutralizes the remaining half of the carbonates and the bicarbonates. The addition of the sulfuric acid volume needed to reach the phenolphthalein endpoint to the amount needed to reach the methyl orange endpoint leads to a calculation of the "total alkalinity."

Sometimes it is desirable to attempt a calculation of the concentrations of individual contributors to alkalinity. Simplified calculation procedures summarized in Table 1 are based upon the following concepts:

(1) Hydroxides, carbonates, bicarbonates are usually the major sources of alkalinity in natural waters.

(2) Hydroxides and bicarbonates are incapable of existing together in the same solution. (Assumed, but not true)

(3) The hydroxide supply is essentially exhausted by titration to the phenolphthalein endpoint.

(4) One half of the carbonates is titrated upon reaching the phenolphthalein endpoint.

(5) The bicarbonates and the remaining half of the carbonates are titrated when proceding from the phenolphthalein endpoint to the methyl orange endpoint.

Table 1. Alkalinity Relationships

TITRATION RESULT	HYDROXIDE ALKALINITY	CARBONATE ALKALINITY	BICARBONATE ALKALINITY
$P=T$	equals T	0	0
$P<\frac{1}{2}T$	0	2P	T-2P
$P=\frac{1}{2}T$	0	T	0
$P>\frac{1}{2}T$	T - 2(T-P) or 2P-T	2(T-P)	0
$P=0$	0	0	T

P = Phenolphthalein Alkalinity T = Total Alkalinity

(1) Procedure:

(a) Refer to Delta, Hach, LaMotte kits. The reactions are classical acid-base neutralizations.

$$H^+ + X^- = HX \quad (X^- = \text{any anion of a weak acid})$$

(b) The following procedure using available laboratory materials is suggested (1).

Equipment:

25 ml graduated cylinder

medicine droppers

50 ml Erlenmeyer flask

Buret or 1 ml pipet graduated in 0.1 ml units

Reagents:

Methyl Orange Indicator: Dissolve 0.5 g of methyl orange in 1 liter of distilled water.

Phenolphthalein Indicator: Place 0.5 g of phenolpthalein into 50 ml of ethanol and dilute to 100 ml.

0.1 M Sodium Thiosulfate: Dissolve 2.5 g of $Na_2S_2O_3 \cdot 5\ H_2O$ in 100 ml of distilled water.

0.01 M Sulfuric Acid: Add 3 ml of concentrated H_2SO_4 (18 M) to 1 liter of distilled water yielding 0.05 M H_2SO_4. Dilute 20 ml 0.05 M H_2SO_4 to 100 ml yielding 0.01 M H_2SO_4.

Procedure

1. If present, remove free residual chlorine by adding 1 drop of sodium thiosulfate to a 100 ml sample.
2. Measure a 10 ml sample into the titration flask and add 1 drop of phenolphthalein. If solution is not pink, no free alkalinity is present. Skip Step 3 and proceed to Step 4.
3. Add 0.01 M sulfuric acid to the sample with the pipet or buret. Record the number of ml's needed to reach the pink endpoint. Use this number in the calculation of phenolpha-

lein alkalinity.

4. Add 1 drop of methyl orange indicator.
5. Continue to titrate with 0.01 M Sulfuric acid until the methyl orange endpoint is reached. Record the volume (ml) used and combine this value with the volume (ml) obtained in Step 3. Use this value for the calculation of total alkalinity. (A reference for the endpoint can be prepared by adding 1 drop of methyl orange to 10 ml of pH 4.5 solution prepared by combining 1.36 g $C_2H_3O_2Na \cdot H_2O$ and 10 ml 1 M C $HC_2H_3O_2$ with water to make 100 ml solution.)

Calculations:

For uniformity, alkalinity is expressed as Mg $CaCO_3$/l even though there may be no $CaCO_3$ present. The equation for the phenolphthalein alkalinity is

$$\text{Mg } CaCO_3/l = \frac{A \times (\text{Molarity of } H_2SO_4) \cdot \times 100{,}000}{\text{Volume of sample}}$$

where A equals ml of the titrant used to reach the phenolphthalein endpoint and the concentration of the sulfuric acid is expressed as molarity.

This can be reduced to:

$$\text{mg CaCO /1} = A \times 100$$

if a 10 ml sample is used and the sulfuric acid is 0.01 M.

In the same way, the total alkalinity is calculated as

$$\text{mg } CaCO_3/1 = B \times 100$$

where B is the TOTAL number of ml needed to reach the methyl orange endpoint.

(2) Reference

1. Standard Methods for the Examination of Water and Wastewater, American Public Health Association, 12th Ed., New York, pp. 48-50 (1965).

c. pH

pH is a measurement which reflects the instantaneous free hydrogen ion concentration in a water sample. Free hydrogen and hydroxide ions exist in equilibrium im all aqueous solutions. If these ions are present in equal amounts the sample is described as neutral and has a pH value of 7. If the hydrogen ion concentration is less than the hydroxide ion concentration the solution is said to be basic and has a pH value greater than 7. If the hydrogen ion concentration is greater than the hydroxide ion concentration the solution is acidic and has a pH value less than 7 (Fig. 1).

acidic basic

(H^+) (OH^-) (H^+) (OH^-)

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14

/ neutrality

(H^+) = (OH^-)

Fig. 1 - pH Relationships

It is essential to recognize that pH is not a measurement sensiitive to the presence of substances which may contribute to the total acidity or alkalinity of a given sample. Consequently, it must not be confused with the results of total acidity and alkalinity determinations. Samples which possess a neutral pH may possess high acidity and/or alkalinity values. Because natural waters are buffered by the CO_2, HCO_3, CO_3 system to a pH range of 6.5 to 7.5, marked deviations from neutrality are generally the result of industrial contamination.

The pH of water samples is usually determined by either colorimetric or electrometric techniques. Colorimetric procedures rely upon chemical substances which undergo color changes with change in pH. There are numerous reagents which demonstrate this phenomenon;

however, each is effective as a pH indicator within a limited pH range only. A versatile pH measurement system must contain numerous indicators covering the entire pH spectrum. These indicators are either impregnated on paper strips, used separately in solution form, or combined to create a "universal" or "wide-range" indicator solution.

Electrometric techniques yield the greatest accuracy. They employ meters which, by means of a glass electrode, detect differences in electric potential which occur with differing pH values. Once the meter is properly calibrated, pH readings are read directly from the instrument scale.

(1) Procedure

  (a) Refer to the Delta, Hach or LaMotte kits. All three utilize colorimetric procedures.

  (b) As alternatives to the kits, the following procedures are recommended.

    (1) Purchase universal indicator or a good quality pH paper from any chemical supply house and use according to the accompanying instructions.

    (2) Use a pH meter. Models differ in operation; therefore, instructions for their use must

be obtained from the manufacturer. The pH of a given sample should be obtained promptly to prevent changes due to reactions with CO_2 from the air or loss of CO_2 to the air.

2. Dissolved Gases

   a. CO_2 - see end of this section (3) for material.

   b. Chlorine (residual)

Both free and combined forms of chlorine are used as disinfectants in attempts to curb waterborne diseases. Chlorine does not occur naturally in water but may enter through sewage treatment effluents and industrial wastes.

In the quantitative determination of chlorine an organic compound, orthotolidine, is oxidized in acid solution by both free and combined forms of chlorine. This produces a yellow colored compound, holoquinone, which is measured colorimetrically.

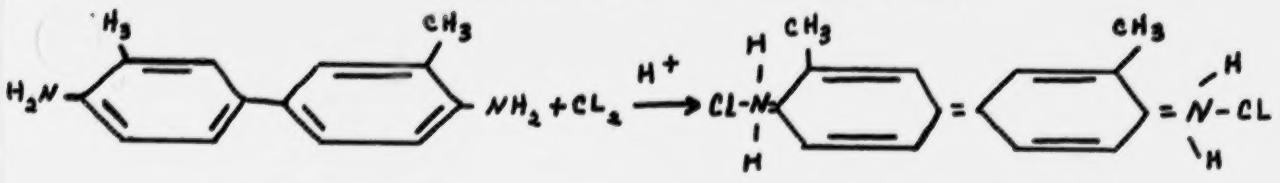
An alternate method which corrects for color interferences is known as the orthotolidine-arsenite method. Total residual chlorine is measured in the usual way with orthotolidine as described above A second test which serves as a blank is prepared by introducing sodium arsenite solution before adding the orthotolidine. The arsenite, being a much stronger reducing agent than orthotolidine, reduces both free and combined chlorine. This prevents their reaction with the orthotolidine. Any color present in this second test is due to interference by other chemical substances and the reagents being used. The total residual chlorine level can be calculated as follows:

Total chlorine residual and (Test 1) - Interfering Color (Test 2) = Total Residual Chlorine

(1) Procedure:

(a) Refer to Delta kit

For clear waters, Delta uses the orthotolidine method. The reaction is as follows:



orthotolidine

A holoquinone (yellow)

For turbid waters, Delta uses the Orthotolodine-Arsenite method as described above.

(b) Refer to Hach kit - Because of color fading, Hach has developed a modified orthotolidine reagent called O-ToliVer which stabilizes the final color for longer periods of time. The reaction is similar to that in the Delta kit.

(c) Refer to the LaMotte kit - It uses the orthotolidine method as described above.

c. Dissolved Oxygen

Dissolved oxygen is an essential substance for the support of most aquatic life. Its concentration in water (normally very low with that in air) varies with fluctuations in such factors as temperature, types and concentrations of dissolved and suspended solids, biotic activity, and agitation of the water. Both depressed and elevated (supersaturated) dissolved oxygen levels are encountered in aquatic studies. In view of our understanding of the biological role of DO, deleterious effects of low or nonexistent levels of DO are hardly surprising. Harmful effects accompanying DO supersaturation of water supplies have not been so readily anticipated. However, fish have demonstrated low tolerance to DO supersaturation as indicated by an increased incidence of mortality and disease in such waters (1,2).

Regardless of the test used for determination of DO, the sampling procedures must avoid aeration and warming. Moreover, the test must be done immediately or the oxygen must be fixed if chemical and biochemical influences are to be avoided. The Azide-Winkler method, an accurate and feasible test for

DO, eliminates interference by nitrite ions through the use of sodium azide. Dissolved oxygen is fixed by the addition of manganese sulfate and an alkali-iodide-azide reagent. In this reaction, the oxygen oxidizes manganous ions to manganese oxyhydroxide; $Mn\ O(OH)_2$. Under acid conditions (obtained by adding concentrated sulfuric acid) the manganese oxy hydroxide oxidizes iodide ions to produce free iodine. The amount of free iodine produced is equivalent to the dissolved oxygen originally present. Following titration to a pale straw color with sodium thiosulfate, starch is added and the titration is continued until the blue color disappears. With clean water samples, the titration may be delayed under acid conditions for up to 6 hours. Prompt titration is required for polluted water.

1. Procedure (3)

   (a) Azide-Winkler method - for use in lab without kit.

   Apparatus:

   4-5 ml pipettes

   Buret, graduated in 0.1 ml units with a 50 ml capacity.

   BOD bottles, 300 ml capacity.

Erlenmeyer flask, 250 ml.

Reagents:

Manganese sulfate solution: Dissolve 480 g $MnSO_4 \cdot 4H_2O$ in distilled water, filter and dilute to 1 liter.

Alkali-iodide-azide reagent: Dissolve 500 g NaOH and 150 g KI in distilled water and dilute to 1 liter. To this solution add 10 g NaN_3 dissolved in 40 ml of distilled water. This reagent should not give a color with starch solution when diluted and acidified.

Concentrated sulfuric acid: Use concentrated reagent grade acid (H_2SO_4). Handle carefully!

Starch solution: Prepare a paste of 5-6 g soluble starch in a small amount of distilled water. Pour this paste into 1 liter of boiling distilled water, allow to boil a few minutes and let settle over night. Use the clear supernate.

Sodium Thiosulfate solution: Dissolve 24.82 g $Na_2S_2O_3 \cdot 5\,H_2O$ in boiled and cooled distilled water and dilute to 1 liter. Preserve by adding 0.4 g of NaOH per liter.

Working sodium thiosulfate titrant 0.0375M:

Prepare by either diluting 375 ml sodium thiosulfate stock solution to 1 liter or by dissolving 9.30 g $Na_2S_2O_3 \cdot 5H_2O$ in freshly boiled and cooled distilled water and dilute to 1 liter. (For standardizing the sodium thiosulfate, refer to Standard Methods p. 407).

Procedure:

In the field:

1. Fill a 300 ml glass stoppered bottle with sample water by allowing the sample to enter through a glass or rubber tube which extends to the bottom of the bottle. An overflow displacing the bottle contents 2-3 times is necessary to ensure that the test sample has not been exposed to the air. Stopper the bottle immediately upon removing the tube. Be sure that no bubbles are trapped within the bottle.
2. Add 2 ml. manganese sulfate to the collecting bottle by means of a pipette inserted just below the surface of the liquid.
3. Add 2 ml alkali-iodide-azide reagent in the same manner.
4. Stopper with care to exclude air bubbles and mix by inverting the bottle several times. When the precipitate settles shake

again and allow to settle.

Note: the oxygen is fixed according to the following reaction

$$Mn^{++} + 2\ OH^{-} + \tfrac{1}{2}\ O_2 \rightarrow \underset{\text{(br. floc)}}{MnO(OH)_2\ (S)} + \quad \text{(eq.1)}$$

In the Lab:

5. Add 2.0 ml concentrated H_2SO_4 with the pipette above the surface of the liquid; stopper, and invert several times to dissolve the precipitate.

   Note: With the addition of sulfuric acid the proper low pH conditions are obtained for the destruction of interfering NO_2^- by the sodium azide which was added in the alkali-iodide-azide reagent above. The following reactions occur:

   $$NaN_3 + H^+ \rightarrow HN_3 + Na^+ \quad \text{(eq.2)} \qquad 1$$

   $$HN_3 + NO_2^- + H^+ \rightarrow N_{2(g)} + NO_{2(g)} + H_2O \quad \text{(eq.3)}$$

   Under the same pH conditions, the Mn+4 oxidizes I^- to produce free I_2 as follows;

   $$MnO(OH)_2 + 2\ I^- + 4\ H^+ \rightarrow Mn^{++} + I_2 + 3H_2O \quad \text{(eq.4)}$$

6. If an Erlenmeyer flask, titrate the 300 ml sample with 0.0375 M sodium thiosulfate to a pale straw color.

7. Add 2 ml of starch solution. A blue color forms indicating the presence of molecular iodine, I_2. Continue titrating until the molecular iodine is reduced to iodide ion as indicated by the disappearance of the the blue color.

   Note: The reaction is

   $2\ S_2O_3^{=} + I_2 \quad S_4O_6^{=} + 2\ I^-$ (eq.5)

8. Record the total amount of sodium thiosulfate used.

Calculations:

1 ml. of 0.0375 M $Na_2S_2O_3$ is equivalent to 0.2 mg DO per 300 ml. sample as follows:

According to (eq. 5) $S_2O_3^{=}$ loses 1 electron so that 1 liter of 0.0375 M $Na_2S_2O_3$ will lose 0.0375 moles of electrons (or 1 ml will lose 3.75×10^{-5} moles of electrons). To change 1 mole of molecular oxygen (O_2) to $O^{=}$ requires 4 moles of electrons. 3.75×10^{-5} moles of electrons will reduce approximately 9.4×10^{-6} moles of molecular O_2. Since 1 mole of O_2 has a mass of 32 g., 9.4×10^{-6} moles has a mass of 0.0003 g. or 0.3 mg. Each millilter of sodium thiosulfate used in the titration of a 300 ml sample indicates the presence of 0.3 mg O_2/300 ml or 1 mg O_2/liter (1 ppm).

Summarizing: Each ml. of sodium thiosulfate added in steps 7 and 8 equals 1 mg/l DO (1 ppm).

(b) As an alternative to the laboratory method described above, refer to either the Hach or LaMotte kits. They utilize chemical principles outlines for the laboratory method with exceptions as follows:

(1) Mach: Substitutes phenylarseneoxide (POA) for the sodium thiosulfate titrant.

(2) LaMotte: Utilizes an unmodified Winkler procedure; consequently, it is subject to interference by nitrite ions.

2 References:

1. McKee, J.E., Wolf, H. W., Water Quality Criteria, Calif. State Water Quality Control Board, 2nd Ed., Pub. #3-A, Sacramento, p. 181 (1963).
2. Ibid.
3. Standard Methods for the Examination of Water and Wastewater, American Public Health Association, 12th Ed., New York, pp. 415-419 (1965).

a. Carbon Dioxide prior to Chlorine

Refer to Section (2), Unionized (Bound)

Acidity, of Acid-Base Parameters.

3. Dissolved and Suspended Solids

a. Chloride

The chloride ion is a component of many salts and most living organisms. Because chloride salts are usually soluble, ion find its way into natural waters by phenomena such as erosion and leaching. Examples of other common chloride sources include sea water intrusion, human and animal sewage, fertilizers, industrial wastes, and winter salting of highways.

The gradual addition of a mercuric nitrate or silver nitrate solution to a water sample containing an indicator. The mercuric or silver ions combine with the chloride ions until the chloride supply is essertially depleted. At this point, mercuric or silver ions form a colored complex by reacting with the indicator. The amount of mercuric nitrate or silver nitrate solution added indicates the chloride ion concentration.

(1) Procedure:

(a) Refer to the Hach, Delta, or LaMotte kits if they are available. These kits utilize the following reactions.

Hach Kit: 1) $Hg^{++} + Cl^{-} = HgCl_2$

2) Hg^{++} + Diphenylcarbazone = purple

complex

Delta & LaMotte Kits:

1) $Ag^+ + Cl^- = AgCl$

2) $2\ Ag^+ + CrO_4 = Ag_2CrO_4$ (red color)

(b) If a commercial kit is not available, the following procedure which uses the reaction cited in "b" above is suggested.

Equipment:

Buret, 25 ml.

Porcelain evaporating dish, 250 ml.

Glass stirring rod.

Assorted beakers, graduates, one-liter volumetric flasks, and bottles as needed.

Five-ml pipet.

Reagents:

Silver nitrate, 0.0141 M: Dissolve 2.396 g silver nitrate ($AgNO_3$) in distilled water and dilute to 1 liter in a volumetric flask. Standardize against 0.0141 M sodium chloride solution. One ml silver nitrate solution equals approximately 0.500 ml 0 1^-.

Sodium Chloride, 0.0141 M: Dissolve 0.8241 g of sodium chloride (NaCl) in distilled water and dilute to 1 liter in a volumetric flask. One ml sodium chloride solution equals 0.500 mg Cl^-.

Potassium chromate indicator: dissolve 50 g potassium chromate (K_2CrO_4) and dilute to 1 liter with distilled water.

Procedure:

1. To standardize the silver nitrate, add exactly 20 ml of 0.0141 M sodium chloride to 1 ml of potassium chromate indicator in a porcelain evaporating dish. Titrate as per step "4" below. Then calculate the normality constant as follows:

   $$\frac{\text{ml } AgNO_3}{20} \times 500 = \text{Normality constant}$$

2. Place 100 ml sample or a smaller quantity diluted to 100 ml with distilled water in a porcelain evaporating dish.
3. Add one ml of potassium chromate indicator, with a pipet.
4. Add silver nitrate solution from a buret, stirring the dish contents until a uniform pinkish-yellow endpoint is reached. Record the ml of silver nitrate added.
5. Repeat steps 2, 3, and 4 above using 100 ml of distilled water as a blank in place of the sample.

6. Calculate the final result as follows:

$$\text{mg/l } Cl^{-} = \frac{(\text{ml } AgNO_3 \text{ for sample} - \text{ml } AgNO_3 \text{ for blank})\ (\text{Normality Constant}}{\text{ml original sample}}$$

(2) References:

1. Water Pollution Control Federation, *Simplified Laboratory Procedures for Wastewater Examination*, WPCF Publication, No. 18, pp. 45-46 (1968).

b. Hardness- Calcium, Magnesium, Total.

Hardness is a water quality parameter which limits the lathering or foaming ability of soaps and increases the tendency of a water sample to produce scale in pipes, heaters, and boilers. Hard water is caused by the presence of divalent ions such as Calcium (Ca^{++}) and magnesium (Mg^{++}). Additional ions, e. g., Sr^{++}, Mn^{++}, Fe^{++}, can cause hardness but are present only in limited amounts in most water supplies. If their concentrations are elevated, they should be included in calculations of total hardness.[1] All of these cations enter water sources via industrial wastes, sewage, and contact with soil and rock formations.

The chemical determination of total hardness involves the titration of a water sample to which an indicator, e.g., Eriochrome Black T has been added. The substance EDTA is used as the titrant because of its ability to complex with divalent cations. Prior to titration, the indicator forms a red complex with Ca^{++} or Mg^{++}. During titration in a specific pH range the red indicator releases its bound cations to the EDTA and reverts to its blue pigment. Total hardness is calculated from the amount of EDTA needed to reach the blue endpoint.

In the determination of calcium hardness, magnesium is precipitated as magnesium hydroxide by the addition of alkali. The rest of the procedure is completed as outlined above. Magnesium hardness is calculated by subtracting the calcium value from the total hardness figure.

(1) Procedure

(a) For total hardness, refer to the Hach or LaMotte kits. The following reactions are employed.

(Eriochrome Black T) blue color $\overset{M^{++}}{}$ (M Eriochrome Black T) wine red complex

EDTA $\overset{M^{++}}{}$ (M·EDTA) colorless complex

(a) M^{++} = any divalent cation

(b) EDTA = ethylenediaminetetracetic acid

(b) For calcium hardness, refer to the Hach, LaMotte or Delta kits. Following the addition of sodium hydroxide or potassium hydroxide to precipitate magnesium hydroxide as follows,

$$Mg^{++} + 2\ OH^- = Mg(OH)_2$$

the reaction of the Hach and LaMotte kits are as described above. While the Delta kit uses different reagents, it appears to utilize a similar process.

(c) Magnesium hardness may be calculated by dtermining the difference between the total hardness and calcium hardness value.

(d) As an alternate procedure, calcium hardness may be evaluated a rough quantitative fashion by the following prcipitation procedure according to the reaction

$$Ca^{++} + C_2O_4 = CaC_2O_4(S)$$

Equipment:

2 test tubes

4 medicine droppers

Reagents:

Stock 0.01M Ca^{++} solution: Add 1.11 g of $CaCl_2$ to 100 ml of distilled water and dilute to 1 liter.

Working Ca^{++} standard (80 ppm Ca^{++}): Add 20 ml of the stock solution to 80 ml of distilled water.

Concentrated ammonia water.

4% Ammonium oxalate: Dissolve 4 g of $(NH_4)_2C_2O_4$ in 50 ml of distilled water and dilute to 100 ml.

Procedure:

1. Prepare a reference sample containing Ca^{++} by placing

20 drops (1ml) of the working Ca^{++} standard into Tube 1.

2. Place 20 drops of the water sample into Tube 2.
3. Add two drops of concentrated ammonia water to both tubes.
4. Add 4% ammonium oxalate dropwise until a reaction is observed. Do not add more than 5 drops.
5. Compare the amount of precipitation in Tube 2 with that in Tube 1. Report your result as being greater than or less than 80 ppm.

(2) Reference:

1. American Public Health Association, Standard Methods for the Examination of Water and Wastewater, 12th Ed., New York, p. 149 (1965).

c. Iron

Ionic forms of iron occur in water as either iron (II) or iron (III) species. Iron (II) is easily oxidized to iron (III) which reacts with hydroxides to form insoluble iron (III) hydroxide thus keeping iron concentrations in mostwater supplies at low levels. While toxic to many organisms, elevated iron concentrations support iron bacteria (which may cause corrosion in pipe lines or structures with formation of slimes, pits, encrustations and other undesirable effects. Dissolved iron originates from soils or rock formations during leaching and erosion processes effected by acidic water flows. Also, there is evidence which suggests that iron enters water sources through changes produced in environmental conditions as a result of biological reactions.[1]

In quantitative iron studies it is necessary to convert all of the iron (III) to the soluble iron (II) form. This is accomplished by dissolving any precipitated iron (III) hydroxide by the addition of hydrochloric acid and reducing the iron (III) species to iron (II) through the action of hydroxylamine, a strong reducing agent. The water sample is then treated with 1,10-phenanthroline which combines with the iron (II) to form an orange-red complex suitable for colorimetric evaluation.

An alternative procedure involves the conversion to iron (II), as described, followed by the addition of ethylenediamine which buffers the water sample and complexes heavy metals which might give erroneously high results. 2,2", 2- tripyridine is added to yield a reddish-purple iron (II) complex for colorimetric study.

(1) Procedure:

(a) Refer to the Hach, Delta, or LaMotte kits.

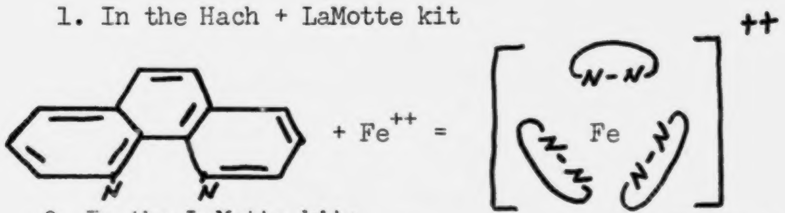
The following reaction sequences are used.

$Fe(OH)_3 + 3\ H^+ + 3\ H_2O$

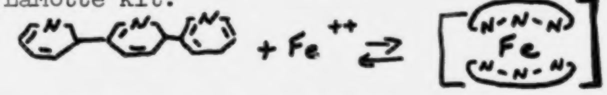
$4\ Fe^{3+} + 2\ NH_2OH = 4\ Fe^{++} + N_2O + H_2O + 4\ H^+$

followed by

1. In the Hach + LaMotte kit



2. In the LaMotte kit:



(2) Reference:

1. Sawyer, C.N., McCarty, P.L., Chemistry for Sanitary Engineers, 2nd Ed., McGraw-Hill, New York, N.Y., pp. 446-448.

d. Nitrate

Nitrate ions are endproducts of the oxidation of nitrogen or nitrogen compounds. They are formed by (1) the nitrogen fixation activity of certain bacteria and algae, (2) the oxidation of atmospheric nitrogen during electrical storms, and (3) the oxidation of nitrogenous compounds (ammonia, nitrites, proteins, certain organics) in both water sources and aerobic sewage treatment systems. Their use in fertilizers as a source of nitrogen for plant protein synthesis constitutes a source of pollution as excess amounts are carried into water supplies by percolation and runoff.

In the suggested procedures, nitrates are measured by reduction by cadmium to nitrite ions followed by reaction with sulfanilic acid to form a diazonium salt. The salt is reacted with 1-naphthylamine hydrochloride to form a red-colored azo dye.

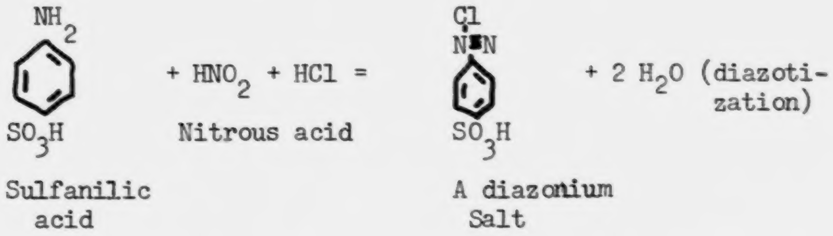
The presence of nitrite ions in the original water sample will cause falsely high nitrate values. A correction is achieved by measuring the nitrite level separately (see Nitrite) and subtracting the resulting nitrite value from the nitrate value obtained in the cadmium reduction method just described.

1. Procedure

(a) Refer to the Hach, Delta, or LaMotte kits.

Their reactions are:

$NO_3^- + Cd = NO_2^- + CdO$ (reduction of NO_3^-)


NH2
SO3H
Sulfanilic acid
+ HNO2 + HCl =
Nitrous acid
Cl
N≡N
SO3H
A diazonium Salt
+ 2 H2O (diazotization)

and samples containing algae and suspended particles which may possess organic phosphorous as a major phosphorous form, emphasis is placed on analytical evaluations of the inorganic forms outlined in Table 1.

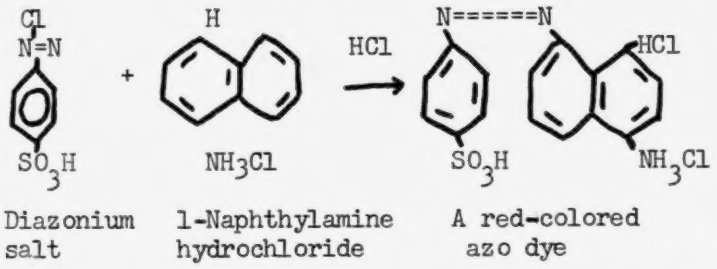
Table 1. - Inorganic Phosphates

Polyphosphates*	Orthophosphates*
(meta) $(MPO_3)x$	MH_2PO_4
(pyro) $M_4P_2O_7$	M_2HPO_4
(tri) $M_5P_3O_{10}$	M_3PO_4
(tetra) $M_6P_4O_{13}$	

* M = any monovalent cation.

These determinations are considered significant because of our increased awareness of the role of phosphates in life processes (ATP, enzyme function, buffering) combined with their extensive use in fertilizers, detergents, water softeners and as nutrients in the biological degradation of sewage.

The suggested procedures detect only orthophosphates; consequently, it is necessary to convert the polyphosphates to the ortho form if a reliable measure of the inorganic phosphate content is to be obtained. This process occurs in all aqueous systems but may take from hours to several days for completion under field conditions. In the laboratory, the conversion is hastened


Cl
N=N
SO3H
+
H
NH3Cl
HCl
N======N
HCl
SO3H
NH3Cl
Diazonium salt
1-Naphthylamine hydrochloride
A red-colored azo dye

e. Nitrite

Nitrites are intermediates in the chemical or biological modification of nitrogenous compounds such as ammonia, nitrates, certain organics, dyes, and proteins. Accordingly, they may occur in water supplies containing such substances.

Nitrites are measured by conversion to a diazonium salt through reaction with sulfanilic acid. Upon reaction with 1-naphthylamine hydrochloride, a red-colored dye **develops** which is easily measured by colorimetric procedures.

(1) Procedure

(a) Refer to the Hach, Delta, or LaMotte kits. The chemistry is described by reactions (2) and (3) of the Nitrate Ion section.

f. Phosphate

The phosphate ion exists in both organic and inorganic forms. With the exception of bottom sediments, by boiling the sample in an acidic solution. If organic phosphorous is to be included in the analysis, it must be converted to the orthophosphate form through oxidation by sodium persulfate (refer to Standard Methods).

Detection of the orthophosphate form is accomplished by reacting it with ammonium molybdate to form ammonium phosphomolybdate. This product is subsequently reduced to molybdenum blue by reaction with stannous ions.

(1) Procedure

(a) Refer to the Hach, Delta, or LaMotte kits if they are available.

(1) $PO_4^{-}3 + 12\ (NH_4)\ _2MoO_4 + 24\ H^{+} = (NH_4)_3PO_4 \cdot 12\ MoO_3 + 21\ NH_4^{+} + 12\ H_2O$

(2) $(NH_4)_3PO_4 \cdot 12\ MoO_3 + Sn^{++} = (\text{molybdenum blue}) + Sn^{+}4$

(2) The following alternative procedure for orthophosphate only is suggested. The reactions just described are utilized.

Equipment:

2 test tubes

3 medicine droppers

Reagents:

Stock solution - (0.001M phosphate solution)add 0.136g KH_2PO_4 to distilled water making total volume 1 liter.

Working Standard ppm H_2PO_4 add 10 ml of stock solution to 990 ml of distilled water.

Ammonium molybdate - Nitric Acid Reagent - dissolve 15g of ammonium molybdate in 300 ml of water. Add 100 ml of nitric acid 1:1 dilution of conc. HNO_3 and saturate with ammonium nitrate.

Procedure

1. Prepare a reference sample containing phosphate ions by placing 20 drops of working standard in Tube #1.
2. Place 20 drops of the water sample into Tube #2.
3. Add 10 drops of the ammonium molybdate-nitric acid reagent to each tube.
4. Add a few crystals of stannous chloride to both tubes. A blue color should appear if orthophosphate ions are present.
5. Compare the intensity of the blue pigment in Tube 2 with that of Tube 1. Report your result as having less than or greater than 1 ppm orthophosphate.

g. Sulfate

The sulfate ion, a complex of sulfur and oxygen, is capable of serving as an oxygen donor for biochemical oxidations occuring under anerobic conditions. This action results in the conversion of the sulfate ion to the sulfide form which equilibrates with hydrogen ions to form hydrogen sulfide. The latter substance possesses an objectionable "rotten egg" odor and is capable of being oxidized by sulfur bacteria to form sulfuric acid. The sulfate ion is derived from sewage, industrial and agricultural effluents, erosion and percolation of water through pyrite or sphalerite ore deposits.

Analytical techniques for sulfates are based upon the formation of insoluble barium sulfate by the addition of barium ions. The resulting solid may be collected, dried and weighed or be kept in colloidal suspension by the use of a conditioning reagent containing hydrochloric acid, sodium chloride, glycerol and other organic compounds and then measured by turbimetric procedures. At least one titrimetric procedure is available which involves the gradual addition of barium chloride to a water sample containing an indicator. The barium ions precipitate with the sulfate ions until the sulfate ion supply is essentially depleted. Excess barium ions then combine with the indicator to produce a color change. The sulfate level is calculated from the amount of barium chloride needed to achieve the endpoint.

(1) Procedure:

(a) Refer to the Hach or Delta kits. They utilize the following reactions.

(1) Hach kit (Turbidometric Procedure).

$Ba^{++} + SO_4^{=} = BaSO_4$ (solid)

(2) Delta Kit (Tritrimetric Procedure).

$Ba^{++} + SO_4^{=} = BaSO_4$ (solid)

THEN Ba^{++} + Indicator = orange-red complex

(b) An alternative rough quantitative procedure is suggested as follows.

Apparatus:

2 test tubes

4 medicine droppers

Reagents:

Stock 0.01 M SO_4 = solution: Add 1.7 g $MnSO_4 \cdot H_2O$ to 100 ml distilled water and dilute to 1 liter.

Working SO_4 = standard (96 ppm SO_4 =): Add 10 ml of stock solution to 90 ml of distilled water.

6 M Hydrochloric Acid: Dilute concentrated HCl to ½ its original concentration.

0.1 M Barium Chloride: Dissolve 2.08 g $BaCl_2$ in 50 ml of distilled water and dilute to 100 ml.

Procedure:

1. Prepare a reference sample containing $SO_4^=$ by placing 10 drops of the working standard into Tube 1.
2. Place 10 drops of the water sample in Tube 2.
3. Add 2 drops of HCl and 1 drop of $BaCl_2$ to each test tube.
4. Formation of a white precipitate or cloudiness indicates the presence of $SO_4^=$. Compare the amount of cloudiness or precipitation in Tube 2 with that in Tube 1 and report your result as greater or less than 96 ppm. $SO_4^=$.

h. Turbidity

Introduction:

Turbidity limits light penetration within a body of water by causing incident light to be scattered or absorbed rather than transmitted appreciable distances through the sample. Turbid water is caused by the presence of suspended organic and inorganic solids derived from erosion, surface drainage systems, and domestic and industrial wastes. It exerts a negative influence on photosynthesis and water temperature by reducing the amount of light reaching subsurface areas and can, by itself, kill fish and other organisms. Increases in turbidity may follow a chain reaction sequence by providing bacteria and other microorganisms contributing to turbidity with an abundant supply of nutrients required for growth and reproduction.

Turbidity is measured by comparing the interference to the passage of incident light in the questioned sample with that in a standard reference. Although the accuracy of photometric or nephelometric techniques is questionable, such procedures are convenient for approximating turbidity and are used in most commercial kits.

Procedure:

(1) Refer to Hach or Delta kits.

(2) The following method which measures the depth of light penetration can be used to supplement photometric determinations of turbidity. The depth of light penetration is affected by turbidity, but also color.

  (a) Equipment. A home-made Secchi disk costs about $2.00.

    (1) Calibrated rope

    (2) Tempered plywood aide, 20 cm in diameter, with alternate white and black quadrants.

    (3) Eye-bolt, washers

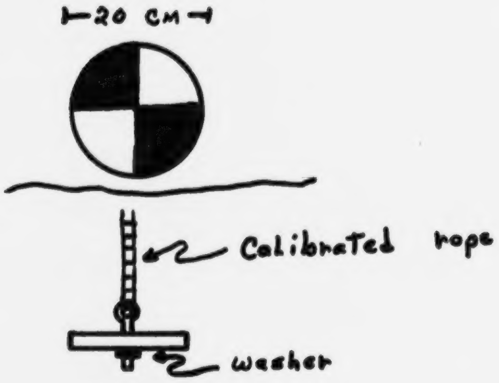


Figure 1.

(b) Procedure

(1) Lower disk and record depth of disappearance.

(2) Lower disk below the recorded point and then slowly raise it. Record the depth at which the disk first becomes visible.

(3) Average the two readings to obtain the Secchi disk readings range between a few centimeters and over 40 meters.

4. Oxygen Demand

a. Biochemical Oxygen Demand (BOD)

BOD values reflect the **quantity** of molecular oxygen required for the decomposition of organic compounds by aerobic biochemical processes. Consequently, BOD values serve as an index of the pollutional strenth of wastes by measuring the amount of oxygen which may be removed from water supplies as these wastes are being aerobically stabilized.

The BOD determination is a bioassay procedure requiring (1) excess O_2, (2) favorable physical conditions, (3) essential nutrients, (4) suitable organisms, and (5) time. While 20 days are usually required to approach complete waste stabilization, the length of the assay is set at 5 days. The shorter period usually allows for the measurement of a substantial fraction of the total BOD. It also minimizes interference by autotrophs, particularly nitrifying bacteria, which aerobically metabolize inorganic nitrogen. These organisms usually require more than 5 days to become established in a fresh sewage sample, but may start promptly in a stream, lake or effluent sample. Aerobic stabilization of inorganic nitrogen does create an increased oxygen demand; however, attempts to evaluate this parameter according to the following procedures are not valid.

Aerobic stabilization of nitrogen components is becoming increasingly important in impounded waters but is not normally included in the described procedure.

Procedure

(1) If the sample has been chlorinated, it is recommended that the BOD not be performed. A good job of chlorination renders the BOD meaningless. However, a dechlorination and reseeding procedure is described in the next section for those who desire to attempt it.

Equipment:

Buret, graduated in 0.1 ml units with a 50 ml capacity.

BOD bottles, 300 ml capacity.

Erlenmeyer flask, 250 ml.

10 ml measuring pipet.

Large-tipped volumetric pipet.

Incubator, controlled at 20° C.

Reagents

Manganous sulfate solution: Refer to the procedure for DO.

Alkaline iodide-sodium azide solution: Refer to the procedure for DO.

Sulfuric acid: Use concentrated reagent-grade acid (H_2SO_4). Handle carefully, since this material will burn hands and clothes. Rinse affected parts with tap water to prevent injury.

Sodium thiosulfate solution: Refer to the procedure for DO.

Starch solution: Refer to the procedure for DO.

Distilled water: Water used for solutions and for preparation of the solution water must be of highest quality. It must contain no copper or decomposable organic matter. Ordinary battery distilled water is not good enough.

Phosphate buffer solution: Dissolve 8.5 g KH_2PO_4, 21.75 g K_2HPO_4, 33.4 g $Na_2HPO_4 \cdot 7H_2O$ and 1.7 g NH_4Cl in distilled water and make up to 1 liter. The pH buffer should be 7.2 and should be checked with a pH meter (or pH paper).

Magnesium sulfate solution: Dissolve 22.5 g $MgSO_4 \cdot 7H_2O$ in distilled water and make up to 1 liter

Calcium chloride solution: Dissolve 27.5 g anhydrous $CaCl_2$ in distilled water and make up to 1 liter.

Ferric chloride solution: Dissolve 0.25 g $FeCl_3 \cdot 6H_2O$ in distilled water and make up to 1 liter.

Dilution water: Add 1 ml each of phosphate buffer, magnesium sulfate, calcium chloride, and ferric chloride solutions for each liter of distilled water. Store at a temperature as close to 20°C as possible. This water should not show a drop in DO of more than

0.2 mg/l on incubation for 5 days.

Procedure:

(1) The percent dilution to be used must be determined. To make this calculation, one should understand that dilution water at room temperature contains approximately 8 mg/l of dissolved oxygen (DO). Consequently, if the oxygen demand of the sample to be tested is greater than 8 mg/l, dilution of the sample has to be made. It is desirable to have at least 1 mg/l of initial oxygen left after 5-day incubation. Table 1. is an aid to estimate the dilutions to use.

*Initial DO=7 mg/l				*Initial DO=8 mg/l			
Percent Dilution (%)	Sample added to 300-ml Bottle (ml)	BOD Range Min. (mg/l	BOD Range Max. (mg/l)	Percent Dilution (%)	Sample added to 300-ml Bottle (ml)	BOD Range Min. (mg/l)	BOD Range Max. (mg/l)
1	3	210	490	1	3	240	560
2	6	105	245	2	6	120	280
3	9	70	162	3	9	80	187
4	12	53	123	4	12	60	140
5	15	42	98	5	15	48	112
6	18	35	82	6	18	40	94
7	21	30	70	7	21	34	80
8	24	26	62	8	24	30	70
9	27	24	56	9	27	27	62
10	30	21	49	10	30	24	56
15	45	14	33	15	45	16	37
20	60	11	25	20	60	12	28
25	75	8	20	25	75	9.6	22
50	150	4	10	50	150	4	12

*Initial DO is the concentration of dissolved oxygen in mg/l of the mixture of the dilution water and the sample immediately after initial mixing.

Table 1.--An Aid in Selection of Percent Dilution for BOD Determination

Raw sewage usually contains about 100 to 300 mg/l BOD so that 1- and 2- percent dilutions generally are used; settled sewage BOD's usually range from 50 to 200 mg/l, and 2- and 3- or 3- and 4-percent dilutions are common; trickling filters use 5 and 10 percent; and for activiated sludge effluents, use 10, 20, or 50 percent depending how how good the effluent is. Very strong sewages or industrial wastes are diluted 1 part wastewater to 10 parts dilution water before making the dilutions of 1- to 2-percent. In this way a range of 1,000 to 3,000 mg/l BOD is covered. However, the inexperienced operator is advised not to try to analyze industrial wastes.

(2) Fill two 300 ml BOD bottles about half-full with dilution water.

(3) Using a large-tipped pipet, measure the precalculated amount of sample into the two 300 ml BOD bottles.

(4) Fill each bottle with dilution water and insert stoppers. See that all air bubbles are excluded.

(5) Fill two additional bottles with straight dilution water and insert stoppers the same way.

(6) Incubate one bottle containing the diluted sample and one bottle containing only dilution water.

(7) Determine the initial DO levels of the diluted sample & of the dilution water by running dissolved oxygen determinations on the two remaining bottles.

(8) After 5 days, run a dissolved oxygen determination on the incubated bottles. Record the DO contents. (The increase or decrease of DO in the bottles

with just dilution water is intended to serve only as a measure of dilution water quality. There should be no increase or decrease than 0.5 mg/l when compared to the initial DO value of the dilution water.)

Calculations:

BOD values are calculated as follows:

$$\frac{100 \times (\text{Initial DO of diluted sample} - \text{DO of sample after 5 days})}{\text{Percent of sample added}} = \text{mg/l (5 day BOD)}$$

(2) Declorination and Reseeding Procedure[2]

Whenever BOD determinations are to be made on chlorinated water samples, sufficient reducing agent must be added to remove the chlorine. After dechlorination, the sample must be "reseeded" with organisms.

Procedure:

(1) Secure an unchlorinated sample of raw sewage or primary effluent about 24 hours prior to the time when you expect to set up dechlorinated and seeded samples for determination of BOD. Collect about one liter of unchlorinated sample and let stand at room temperature overnight. Pour off the clear portion of the sample and use it for the "seed".

(2) Check for the presence of chlorine in the composite

sample proceeding as follows:

a. Carefully measure 100 ml of well-mixed sample into a 250 ml Erlenmeyer flask.

b. Add a few crystals of KI to the sample and dissolve the crystals.

c. Add 1 ml of concentrated H_2SO_4 and mix well.

d. Add five drops of starch.

   (1) If no blue color is produced and chlorine is absent, the BOD of the composite may be determined without further treatment. In this case, all of the chlorine has been "used up" by the water and it may be assumed that a sufficient number of organisms remains so that the full BOD will be exerted.

   (2) If a blue color is produced, titrate the composite sample with 0.025 M $Na_2S_2O_3 \cdot 5H_2O$ to the endpoint between the last trace of blue color and a colorless solution. Make the titration very slowly, counting the drops of sodium thiosulfate used and recording the number.

3. To dechlorinate a sample for BOD testing, measure out another 100 ml portion of the well-mixed composite into a clean 250 ml Erlenmeyer flask. Add

the number of drops of 0.025 M sodium thiosulfate determined necessary for dechlorination in step 2d above. Mix well. Use this sample for determination of BOD. If more sample is needed, place a larger sample into a clean container and add a proportionate number of drops of the sodium thiosulfate for dechlorinating.

4. For seeding of the sample, add 1 ml of the aged seed (step 1 above) to each of the BOD bottles containing dechlorinated sample.
5. Set up samples of the seed for determination of the BOD using 2, 3, and 4 percent (3,6, and 9 ml seed) and determine the 5 day depletion due to 1 ml of seed.

Calculations:

If the sample has been dechlorinated and reseeded as described, the 5 day BOD should be calculated as follows:

$$\frac{B - (A + C)}{D} \times 100 = 5 \text{ day BOD expressed as mg/l}$$

where

A = 5 day DO depletion of seed sample/ml seed

B= Initial DO (mg/l) of diluted sample.

C = DO (mg/l) of sample after 5 days.

D = Percent of sample used.

(3) References

1. Simplified Laboratory Procedures for Wastewater Examination, Water Pollution Control Federation, WPCF Publication No. 18, Washington, D.C., pp. 38-40, (1968).

2. IBID., pp. 41-43.

5. Interpretation.

Aided by natural selection, existing aquatic ecosystems have evolved through geologic time. Organisms have adapted to their environments to the extent that the components of these environments are now the very factors upon which they depend. Deviations from this make-up, especially if sudden, may adversely affect the organisms living there.

Even within a given locale, the environmental conditions which one observes are limitless. Consequently, universal favorable concentrations of dissolved solids, gases, etc., are either exceedingly difficult or impossible to identify. Since toxicity of chemicals varies not only with the types and ages of the organisms concerned, but also with duration of exposure, temperature, accompanying dissolved and suspended substances, flow rate, etc., even generalizations concerning concentrations at which specific substances become toxic are not feasible. Because of these difficulties, favorable, tolerable and toxic concentrations are not indicated in this manual on the premise that such information is, at its best, of little significance or, at its worse, misleading.

The following activities are recommended as aids in the interpretation of chemical data (1).

a. Sample the ecosystem periodically over a long period of time. Identify norms and note all biological and chemical changes, especially those which occur suddenly. Evaluate your data in terms of the entire ecosystem. Chemical determinations are of limited significance alone.

b. Determine, in the laboratory, environmental factors which are favorable or tolerable.

c. Use bioassay techniques to identify responses of organisms to various concentrations of potential toxicants and try to determine permissible levels for the ecosystem under study.

d. Test the laboratory findings in the field to evaluate their validity.

To facilitate interpretation of test results, two tables are included which emphasize those factors which are known to either interfere with chemical tests (Table 1.) or influence toxicity (Table 2.).

6. Bibliography

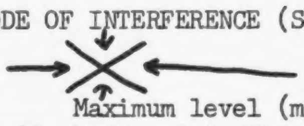
Appendix 1 Draft

Table 1. - Test Interferences*

	Acidity	Alkalinity	Aluminum	Bromide	Chloride	Chlorine	Chromium	Copper	Cyanide	Fluoride	Hardness	Calcium	Magnesium	Hydrogen Sulfide	Iodide	Iron (II)	Iron (III)	Manganous
Acidity			$\overset{e}{X}_{1}$			$\overset{e}{X}_{2}$										$\overset{e}{X}_{1}$		
Alkalinity						$\overset{e}{X}_{2}$						$\overset{c}{X}_{3}$	$\overset{c}{X}_{3}$					
Aluminum						$\underset{.5}{X}$				$-\underset{.5}{X}$		$+\underset{.04}{X}$						
BOD						$\overset{e}{X}$												
CO_2	$+\overset{f}{X}$		$+\overset{f}{X}$				$+\overset{f}{X}$	$+\overset{f}{X}$						$+\overset{f}{X}$		$+\overset{f}{X}$		
Chloride				$\overset{d}{X}_{5}$			$\underset{10}{X}_{6}$							$\overset{e}{X}_{5}$	$\overset{d}{X}_{5}$		$\overset{e}{X}_{5}$	
Chlorine																	$+\overset{d}{\underset{.3}{X}}$	$+\overset{d}{\underset{.01}{X}}_{11}$
DO						$+\overset{d}{X}_{13}$										$-\overset{e}{X}_{13}$		
Fluoride		$-\underset{5000}{X}$	$-\underset{.1}{X}$		$+\underset{7000}{X}$													
Hardness (EDTA)																		
Ca++ (EDTA)		$\overset{c}{\underset{30}{X}}$	$\underset{5}{X}$					$\underset{2}{X}$									$\underset{20}{X}$	$\underset{20}{X}$
Hydrogen sulfide																		
Iron							$\overset{a}{X}$	$\overset{b}{\underset{5}{X}}$	$\overset{a}{X}$									
Mn^{++}					$\overset{a}{X}_{16}$													
Nitrate								$-X$									$\overset{e}{X}$	
Nitrite																	$\overset{e}{X}$	
pH (colorimetric)						$\overset{c}{X}$											$\underset{.04}{X}$	
Phosphates							$-\overset{b}{X}$											
Sulfate																		

KEY

MODE OF INTERFERENCE (See below)



Effect of Interference on Numerical result

Footnote (See below)

Maximum level (mg/e) before interference occurs

Nitrite	pH	Phosphates, Total	Phosphates, Ortho	Phosphates, Poly	Silica	Strontium	Sulfate	Sulfite	Thiosulfate	Ammonia	Turbidity	Temperature	Color	Other
				-X				-X 10						
												X a		X e 4
+X f		+X f								+X f				
	X 8		X e 7 25					X 5	X e 7					
+X d											X b	X 10	X b 16	+X 9
+X 13								-X a 13	-X e 13					
			+X 16	+X 1			+X 200							
	X c 14													
			X e			X d								
								X a 10	X a 10					
X a		X a 15												
											X b		X b	
-X b											X b		X b	
					X 500						X b		X b	

A1-59B

Footnotes: Table 1.

1. Unhydrolyzed aluminum and/or iron (II) sulfate cause difficulty in determining the endpoint. Performence of the titration at boiling temperature alleviates this problem.
2. Free chlorine may be removed by adding 1 drop 0.1 M $Na_2S_2O_3 \cdot SA_2O$ to the titration sample.
3. Calcium carbonate and magnesium hydroxide precipitates cause fading endpoints and should be removed by filtration.
4. The presence of toxic substances such as heavy metals may interfere with BOD determinations.
5. Interfers in silver and mercuric nitrate tests.
6. Interfers in mercuric nitrate test.
7. Interfers in silver nitrate test.
8. pH must be in the range of 7-8. Errors are introduced above and below this range.
9. The presence of algae may result in erroneously high Cl_2 determination.
10. Temperature must be controlled at 20° C, otherwise the Cl_2 concentration will vary.
11. Interference is caused by Manganic Manganese.
12. Color corrections may be made by using the orthotolidine-arsenite method.
13. Azide modification of Winkler overcomes nitrite interferences. Refer to Standard Methods for additional modifications for

14. pH values greater than 10 favor precipitation of $CaCO_3$, thus cuasing drifting endpoints which may yield low results (EDTA Method).

15. Phosphates do not interfere in the tripyridine Method for iron determinations.

16. Periodate method for manganese determinations.

MODE OF INTERFERENCE Table 1.

a. 0 Interferes with reaction mechanism

b. X Interferes with phylometric readings

c. - Interferes with endpoint determination

d. Test does not differentiate

e. Forms interfering ppt under conditions of test

f. Disturb carbon dioxide - carbonate equilibrium

g. Alters reaction rate

h. Alters concentration

*The material for this table was obtained from Standard Methods for the examination of Water and Wastewater. This reference should be consulted for further information.

Table 2. - Interrelationships of ChemicalSpecies Affecting Biological Activity*

	Metallo CN	$CuSO_4$	Pb	Zn	Al	High pH	NH_3	low pH	Cu	High Hardness	Cl_2	$ZnSO_4$	$CdSO_4$	Hg	$NaNO_2$	$NaNO_3$	CN	low DO	Acidity	Temp Inter	CO_2	Low H	Alkalinity	Ca
Acidity	+																							
Alkalinity		-																						
Ca			-	-	-																			
$CO_3^=$						+																		
CO_2							-																	
Cl^-																								
Cl_2								+	+															
Cu										-	+	+	+	+	-	-	-	+						
CN^-								+	-									+	+	+				
Low DO			+	+			+		+								+				+			
Metals										-												+		
Fe^+_3																							+	
Mg																								-

(+) = Synergistic (-) = Antagonistic

---

*The relationships depicted in this table were cited in "Water Quality" Criteria by McKee and Wolf. This reference should be consulted for further information.

a. Standard Methods for the Examination of Water and Wastewater, 13th ed., APHA, AWWA, WPCF, Pub. by American Public Health Association, 1790 Broadway, New York, N.Y. (1971). Includes detailed information concerning the identity, origins and analysis of numerous chemical parameters. It is an indispensable reference for water pollution studies.

b. Sawyer, C.N., McCarty, P.L., Chemistry for Sanitary Engineers, 2nd ed., McGraw-Hill, New York (1968). A lucid presentation of the theory and methods of sanitation chemistry intended for the reader possessing a solid foundation in elementary chemistry.

c. McKee, J.E., Wolf, H.W., Water Quality Criteria, 2nd ed., State Water Quality Control Board, Sacramento, Calif. (1963). Although dated, this is an outstanding compilation of the technical, social and legal history of water quality criteria. Reviews of federal and state policies as well as commentaries on an enormous number of chemical pollutants are included. 3827 references are cited.

d. Report of the Committee on Water Quality Criteria, FWPCA, Superintendent of Documents, U.S. Gov. Printing Office, Washington, D.C. (1968). A compilation of FWPCA water quality criteria recommendations and supporting information.

B. Bacteriology

There are numerous types of bacteria and few environments are incapable of supporting some bacterial life. Certain bacteria, including those used in food processing or those found in the soil, which enable plants to obtain nutrients, are beneficial. Harmful bacteria, however, cause food to decay and are responsible for various diseases.

Water can contain many types of bacteria in large numbers. Some of these bacteria are harmless to man, but certain types, termed pathogenic, cause diseases such as typhoid fever, dysentary and cholera. The possible danger of disease dictates that water be free of pathogenic bacteria. Because the cultivation of pathogenic forms is difficult and requires trained personnel, a group of more easily cultivated bacteria is used to indicate the possible presence of pathogens. These indicator organisms include total coliform, fecal coliform, and fecal streptococci organisms.

1. Total Coliform

Total Coliforms include a group of rod or stick-shaped organisms characterized by their ability to ferment a specific sugar (lactose) at 35° C within 48 hours. Although coliforms are introduced to water supplies via water runoff from soil, drains, etc., they are considered significant as indicator organisms because of their predominance in the intestinal tracts of warmblooded animals. While not all animal wastes contain pathogens, the excrement of diseased animals or animals serving as carriers of pathogens do present health hazards.

The total coliform density is roughly proportional to the amount of excremental waste present. With exceptions, elevated coliform populations are suggestive of significant contamination of excrement of warm-blooded animals. Several factors which cause fluctuations in total coliform populations are summarized in Table B-1

Table B-1

Factors Influencing Total Coliform Levels.

Higher	Lower
1. Sewage intrusion	1. p H changes
2. Nutritive effluents (containing sugar, dairy etc.,)	2. Temperature changes
3. Storm drain overflows	3. Land runoff (prolonged rain)
4. Land runoff (Initial Storms)	4. Toxic Wastes

Coliform population limits have been set by Federal and State health services. These limits vary with the designated use of the water supply and are quite variable within such designations.

Table B-2

Water Quality Criteria with Respect to Total Coliform Populations

	Class of Water	Coliform/100 ml		
		Mass.	N.H.	Vt.
A	Drinking Water	< 1 *	< 1 *	≤ 1 *
B	Waters of highest quality, designated for ingestion after disinfection supplies.	.50	50	50

C	Suitable for bathing and recreation; irrigation and agricultural uses, good fish habitat; good aesthetic value; acceptable for ingestion filtration and disinfection.	1,000	240	1,000
D	Suitable for recreational boating; irrigation of crops not used for consumption without being cooked; habitat for wild life and fish; certain industrial cooling and process use.	Unspecified	--	--
E.	Suitable for aesthetic enjoyment, power, navigation, and certain industrial cooling and process uses.	Unspecified	--	--

* This is a national standard specified by U.S.P.H.S.(1962)

With the exception of drinking water standards, it is anticipated that a national classification system, which is based on types of contact and utilize fecal coliform as a quality criterion will be adopted.

2. Fecal Coliform

Fecal coliform, a component of the total coliform population, are characterized by their ability to reproduce on a special medium (MFC) at a temperature of 44.5 to 50°C.

Because non-fecal coliforms may grow below 44°C, and fewer fecal coliforms grow above 45°C, temperature maintenance within the specified tolerance is critical.

Fecal coliform are gaining notoriety as pollution indices because of their relatively infrequent occurrence except in association with fecal pollution. Moreover, because survival of the fecal coliform group is shorter in environmental water than for the coliform group as a whole, high fecal coliform levels indicate relatively recent pollution.

When accompanied by fecal streptococci counts, fecal coliform values may aid in the differentiation of animal from human waste (Table B-3). However, caution must be exercised in the interpretation of such data because of technical difficulties in performing precuse counts.

Table B-3

Average Individual Density Per Gram Of Feces (Indicator Micro-organisms From Some Animals):

Animal	Fecal Coliform Million	Fecal Streptococci Million	Ratio FC/TS
Man	13.0	3.0	4.4
Duck	33.0	54.0	0.4
Sheep	16.0	38.0	0.4
Chicken	1.3	3.4	0.4
Cow	0.23	1.3	0.2
Turkey	0.29	2.8	0.1
Pig	3.3	84.0	0.04

It is anticipated that National standards for water use will be established according to population densities of fecal coliform as shown in Table B-4.

Table B-4

Water Quality Criteria With Respect To Fecal Coliform Population.

Kind of Water	Recommended Numbers of Fecal Coliforms
1. Water designated for Primary Contact Recreation	1. Should not exceed a log mean of 200/100 ml.
2. Water other than for Primary contact Recreation	2. Should not exceed a log mean of 1000/100 ml.
3. General Recreational Surface Water	3. Average not to exceed 2000/100 ml.

Primary Contact Recreational Activities are defined as those activities in which there is a prolonged and intimate contact with the water involving considerable risk of ingesting water quantities sufficient to pose a significant health hazard.

The Food and Drug Administration recommends that the surface waters above shell fish beds shall not have fecal coliform counts above 70/100 ml.

3. Fecal Streptococci

A fecal streptococcus as used in this discussion refers to any streptococcus commonly found in significant numbers in the feces of human or other warm-blooded animals. Fecal streptococci are spherical organisms which generally occur in pairs or short chains. They are capable of reproducing at 45° C and, in some instances, at 10° C on a selective medium containing sodium azide and other inhibitors.

Because fecal streptococci do not occur in pure water or virgin soil, their presence in water supplies indicates the existence of warm-blooded animal pollution. Their validity as an index of pollution is enhanced by their inability to reproduce in water supplies. Moreover, fecal streptococci are more resistant to salts. Therefore, this group could have special value for salt water investigations.

Fecal streptococci determinations, when accompanied by fecal coliform studies, serve as a valuable tool in the differentiation of animal from human wastes. (Section 2, Table B-3). In intestinal wastes of human origin, the ratio of number of fecal coliforms to number of fecal streptococci tends to be greater than four. In comparison, when such ratios are determined for intestinal wastes from non-human sources, the values tend to be markedly less than 0.7. When interpreting fecal streptococci data, the following three points should be considered.

a. The presence of fecal streptococci in untreated water indicates the presence of fecal pollution by warm-blooded animals.

b. In samples where the source and significance of the coliform group has been questioned, the presence of the streptococcus group should be interpreted as indicating at least a portion of the coliform group were derived from fecal sources.

c. Because of the uncertainties in die-off rates, the absence of fecal streptococci does not necessarily mean that water is bacteriologically safe.

4. General Procedures

a. Sterilization

It is necessary to sterilize all necessary equipment in order to assure that only bacteria from the collected water sample will be counted. Therefore, the following instructions must be followed closely.

Equipment:

Autoclave or pressure cooker.

Items for immediate sterilization.

1) For preparation of media (Procedure b).
   Petri dishes (Number determined by sampling needs).
2) For sample dilution (Procedure e).
   1 - 100 ml graduated cylinder.
   3 - 1 ml pipets.
   3 - 125 ml pipets.
   3 - 125 ml flasks.
   Distilled water.
3) For filtration (Procedure f).
   1, 5, 10 ml pipets (number determined by sampling needs).

Items to be sterilized as needed:

1) For preparation of media (Procedures b and e).
   Collection of bottles containing 0.2 ml 10% sodium thiosulfate ($Na_2S_2O_3.5H_2O$).
2) For preparation of solutions (Procedures c and f).
   Phosphate buffer in closed container.

Procedure:

1) All glassware and distilled water should be autoclaved. Use 15 lb. of pressure at 121°C for 15 minutes. The openings of all flasks and cylinders should be wrapped with aluminum foil. Do not autoclave plastic parts or culture media without consulting the manufacturer's instructions.
2) Plastic parts can usually be sterilized by boiling in a water bath for 3 minutes.
3) Filter membranes come presterilized. However, after use, they may be washed off in 95% ethanal, autoclaved at 12 lbs. for 12 minutes for reuse.
   Note: Reuse membranes for the same medium only.
4) Petri dishes (Millipore) are presterilized. For reuse, they should be soaked in liquid household bleach for 10 minutes and rinsed thoroughly under running water. Then they should be immersed in 70% alcohol for 10 min., and dried on a clean surface. Following assembly, they may be stored for later use.

b. Preparation of Media.

After bacteria are collected and filtered from the water sample, they must be allowed to grow at precise temperatures into visible colonies which can be counted easily. To facilitate growth, the proper nourishment (culture medium) must be provided. Total coliform, fecal coliform and fecal streptococci require different types of culture media prepared as follows.

Equipment: (Note - glassware need not be sterile).

3 - 125 ml flasks.
3 - 100 ml graduated cylinders.
2 - 2 ml pipets.
2 - Glass stirring rods.
1 - Balance.
1 - Heat source.

Reagents and Media

Dehydrated M-Coliform broth (MF Endo Broth).
Dehydrated MFC broth base.
Dehydrated M-enterococcus agar.
Agar
Ethanol (95%).
Rosolic Acid.
Sodium hydroxide.
Distilled water (300 ml).

Procedure:

The following methods describe the preparation of agar media for use without pads. This approach is more convenient for preparation of multiple plates. If absorption pads and broth are preferred, omit the agar and add 2 ml of broth to each pad.

1) Total coliform using M-Coliform or MF Endo Broth base.

    a) Pipet 2 ml 95% ethanol into a 100 ml graduated cylinder and fill to the 100 ml mark, and transfer to a 125 ml flask.

    b) Add 4.8 g of dehydrated M-Coliform or MF Endo broth base and 1.5 g of agar to the diluted alcohol solution. Mix thoroughly. Note: MF Endo broth base can be purchased with agar already added. If this is done, follow the manufacturer's instructions for preparation.

    c) Cover flask with a foil cap and heat the mixture with agititation until it just begins to boil. (Do not prolong the heating or reheat. This reduces the selectivity of the media).

    d) Cover the bottom of each sterile petri dish with the broth. This should be done while the broth is still warm. It will gel as it cools, allowing the filter membrane to be placed directly on it. Three or 4 dishes are normally prepared for each water sample (refer to Section e). Petri dishes prepared in this way, may be refrigerated hours.

2) Fecal coliform using MFC Broth Base.

    a) Dissolve o.8 g NaOH in 50 ml distilled water and dilute to 100 ml.

(b) Dissolve 0.1 g rosolic acid in 10 ml 0.2 M NaOH prepared in Step a.

(c) Place 3.7 g MFC broth and 1.5 g agar into a 125 ml flask.

(d) Pipet 1 ml 1% rosolic acid solution (prepared in (b)) into a 100 ml graduated cylinder and add distilled water to the 100 ml mark. Pour this mixture into the flask containing the agar and broth base.

(e) Place a foil cap on the flask and heat, with continuous agitation, to the boiling point. Remove from the heat immediately to avoid destruction of the selectivity of the medium.

(f) Cover the bottom of each sterile petri dish with the warm medium. Dishes prepared according to these instructions may be refrigerated for one week.

(3) Fecal streptococcus using M-enterocuccus agar.

(a) Add 4.2 g M-enterococcus agar to 100 ml distilled water.

(b) Heat to boiling. Remove from the heat immediately to avoid destruction of the selectivity of the medium.

(c) Cover the bottom of each sterile petri dish with the warm medium. The prepared dishes may be stored in a cool, dark place for one week.

References:

(1) Microbiological Analysis of Water, Millipore Corp., pp. 3 and 5 (1969).

(2) Millipore Experiments in Microbiology, Millipore Corp., pp. 17-19 (1969).

(3) Current Practices in Water Microbiology, U.S. Dept. of the Interior (1969).

c. Preparation of Solutions

(1) Sodium Thiosulfate

Chlorine is added to public water supplies and sewage treatment effluents to kill bacteria. When collecting water samples, it is necessary to "deactivate" any chlorine present to avoid killing bacteria after they are trapped in the collection bottle. If this is not done, false data suggesting low or absent quantities of bacteria may be obtained. Sodium thiosulfate is used to "deactivate" the chlorine and may be prepared and stored. When needed, the correct amount of sodium thiosulfate is added to the collection bottle and is autoclaved to assure sterilization.

Equipment:

1 - 1 ml pipet.

1 - 125 ml flask.

250 ml collection bottles (number determined by sampling needs).

Metal foil or paper.

Reagents:

Sodium thiosulfate ($Na_2s_2O_3.5H_2O$).

Distilled Water.

Procedure:

a) Dissolve 10 g $Na_2S_2O_3.5H_2O$ in 50 ml distilled water and dilute to 100 ml.

b) Add 0.2 ml of this sodium thiosulfate solution to each 250 ml bottle. If glass stoppered bottles are used, place a thin strip of paper in the neck to avoid "Freezing" of the stopper.

c) Seal cap and neck with foil and autoclave using 15 lb. pressure at 121°c for 15 minutes. After the bottles are sterilized, they should remain sealed until the time of collection. Label each bottle to identify it as sterilized and ready for use.

2) Preparation of Phosphate buffer.

The collected water samples are to be poured through a membrane filter to trap the bacteria in a later step. It is necessary to rinse the funnel with a sterile phosphate buffer solution to assure that all bacteria are washed onto the membrane. The phosphate buffer may be prepared at any time and sterilized when needed for use.

Equipment:

1 - 500 ml flask.

1 - 1 liter flask.

1 - 1 liter glass bottle (preferably with glass stopper).

2 - 2 ml pipets.

pH meter or close range pH paper.

Reagents:

Potassium dihydrogen phosphate (KH_2PO_4).

Sodium hydroxide.

Distilled water.

Procedure:

a) Dissolve 34.0 g KH_2PO_4 in 250 ml distilled water and dilute to 500 ml.

b) Prepare a 1 M NaOH solution by dissolving 4 g NaOH in 50 ml of distilled water and diluting to 100 ml.

c) Add the 1 M NaOH drop by drop to the solution of KH_2PO_4 (Step a) until the pH is 7.2. Read the pH using a pH meter.

d) Dilute the adjusted solution to 1 liter with distilled water. Label the solution "Stock Phosphate" and store for later use.

e) Add 1.25 ml of this phosphate solution to each liter of distilled water being converted to "working" phosphate buffered water.

f) Autoclave the buffered water in a closed glass bottle using 15 lb. pressure at 121°C for at least 15 min. Be sure to allow the autoclave pressure to drop slowly!

d. Collection of Water Sample.

When collecting a water sample, it is important to select a location which is representative of the body of water. The collection of water too close to the shore or withing stagnant areas may not yield a representative sample. A thorough analysis involves sample collection at varying depths, i.e. about every three feet. However, analysis for recreation usage require only that a sample be taken one foot under the surface in the middle of the swimming area. For larger streams or rivers, a sterile device can be lowered from a bridge into the main current and filled. The sample must not be contaminated by surface scum or unnatural turbidity at any time during or after the collection.

Equipment:

250 ml sterilized collection bottles containing o.2 ml sodium thiosulfate solution (added before sterilization).

Procedure:

1) Remove the foil hood and paper strip from the stopper of the sterile bottle.
2) Place the entire bottle under the water in an inverted position and turn it upright. Keep your hands clear of the water entering the bottle. In moving water, it is wise to keep your hands downstream relative to the neck.
3) Fill the bottle about 2/3 full and replace the stopper while the entire unit is still submerged. The air space is left in the bottle to allow adequate mixing of the

sample later. The bottle should remain sealed until the sample is needed. It must be refrigerated if there is to be a time lapse prior to culturing. (A maximum storage time should be set at 6 hours).

e. Filtration Volumes - Selection and Dilution.

In using membrane filtration as a means of detecting bacteria in water, definite limitations arise concerning the number of countable bacteria colonies on each membrane filter. If too many colonies develop, some may be fused together making accurate counting impossible. If there are not enough, the count may not be representative. Therefore, certain ranges of colonies on each membrane are used as criteria for selecting the dishes which will give the most accurate representation of the bacterial density population (Table B-5).

Table B-5

Recommended Ranges of Colony Counts for Membrane Filtration. Techniques.

Test	Number of Colonies	
	Minimum	Maximum
Total coliform	20	80
Fecal coliform	20	60
Fecal streptococci	20	100
Total counts	20	200

7

The selection of sample volumes which result in counts within the above ranges depends upon the actual bacterial population of the sample. A summary of relationships which exist between filtration volume bacterial levels within samples is presented in Table B-6

Table B-6

Ranges Covered By Representative Filtration Volumes

Ml sample filtered	Bacterial count per 100 ml based on 20 colonies	60 colonies	80 colonies	100 colonies
100	20	60	80	100
10	200	600	800	1000
1	2000	6000	8000	10,000
0.1	20,000	60,000	80,000	100,000
0.01	200,000	600,000	800,000	1,000,000

As indicated in the Table, a moderately polluted lake containing several thousand organisms/100 ml would require the filtration of at least 1 ml undiluted water.

1) Procedure for selection of filtration volumes.

A direct calculation of the filtration volume can be made if there is prior knowledge of the bacterial population density in the water under study. The following relationship is utilized:

$$\text{Sample filtration volume (ml)} = 100 \times \frac{A}{\text{average count/100 ml}}$$

where A = midrange number of colonies for an acceptable plate count which varies according to the organisms being detected as follows:

A = 50 for total coliform counts.

A = 40 for fecal coliform counts.

A = 60 for fecal streptococci counts.

As a sample problem consider a stream with an estimated total coliform level of 25,000/100 ml. The calculation is:

$$100 \text{ X } \frac{50}{25{,}000 \text{ total conlif/100 ml}}$$

thus giving a required filtration volume of 0.2 ml.

To avoid disappointing results, 3-4 different volumes should be analyzed to increase the liklihood that at least one membrane will possess an acceptable number of colonies. The following guidelines may aid in the selection of these varying filtration volumes.

1) Total coliform counts should be based on filtration volumes varying by a factor of 4, or less.
2) Fecal coliform counts should be based on filtration volumes varying by a factor of 3, or less.
3) Fecal streptococci counts should be based on filtration volumes varying by a factor of 5 or less.

If no prior bacteriological data is available for a body of water under investigation, Table B-7 will be of assistance.

Filtration Volumes for Waters Not Previously Studied

Source	Filtration Volumes (ml) * Total Colif.	Fecal Colif.	Fecal Strep.
Unpolluted Raw Surface Water	1,4,15,60 (33-8000)	1,3,10,30 (67-6000)	1,5,25,100 (20-10,000)
Polluted Raw Surface Water	.02,.08,.15,.5 (4,000-400,000)	.1,.3,1.0,3.0 (670-60,000)	0.1,0.5,2.0 for Animal Pollution 1000-100,000 (0.2,1.0,5.0) or (400-50,000)
Sewage and Dilute Sewage	.0003,.001,.003, .01 (200,000-27,000,000)	.0003,.001,.003 (670,000-20,000,000)	0.2x,1x,5x Total Colif. for animal Pollution 1x,5x,25x Total Colif. otherwise

* Ranges/100 m. covered by the recommended volumes are enclosed in parenthesis.

2) Procedures for dilution.

If the filtration volume is less than 0.1 ml it is necessary to dilute the sample. The following procedure is for preparation of a 1:1,000,000 dilution. If a smaller or larger dilution is desired, terminate or extend the steps as necessary.

To choose the correct dilution, it is convenient to change the filtration volume to scientific notation involving a volume that can be easily pipetted. For example, 0.002 ml can be written as 0.2 ml x 10^{2}. Then 0.2 ml of a 1:100 (or 10^{-2}) dilution can be pipetted for filtration.

Equipment:

3 - 1 ml pipettes (sterilized)

1 - 100 ml graduated cylinder (sterilized)

3 - 125 ml flasks (sterilized

Distilled water (sterilized)

Procedure:

(a) Place exactly 99 ml sterile distilled water into each of three sterile flasks.

(b) Shake the sample bottle thoroughly to assure a uniform distribution of bacteria.

(c) Add 1 ml sample water to 1 flask containing 99 ml sterile distilled water. Mix well. This gives a dilution of 1:100.

(d) Remove 1 ml of mixture from flask 1 and place into flask 2. Mix well. This gives a 1:10,000 dilution.

(e) Remove 1 ml of mixture from flask 2 and place into flask 3. Mix well. This gives a 1:1,000,000 dilution. (For higher dilutions, continue this procedure).

f. Preparation of Filter for Incubation

Now that the glassware is prepared, the sample collected and diluted and the petri dishes filled with medium, you are ready to catch and prepare the bacteria to grow. When the water sample is passed through the membrane filter in the filtration apparatus, the bacteria in the water are trapped on the filter. Then by removing the filter and placing it in a petri dish prepared with appropriate nutrients, the bacteria are ready for growth in the incubator. Because of the need to transfer the filter from the filtration apparatus to the petri dish, it is essential to follow the aseptic techniques outlined below.

Equipment:

Filtration apparatus *

Vacuum system (syringe, hand pump and fillings or standard vacuum pump)

Forceps without corrugations on the inside of the tips.

Methanol or ethanol.

Gas burner

Large, wide container for a boiling water bath (if filtration apparatus not presterilized)

Stand to support flask over burner

Sterilized petri dishes containing nutrients

Flasks with diluted samples of water being tested

25 ml graduated cylinder-sterilzed-one for each different water sample

Pre-sterilized membrane filters

Sponge or cloth

100 ml beaker for soaking forceps

Alcohol lamp

Sterilized pipettes (Number and capacity is determined by sampling needs)

* This procedure assumes apparatus to be unsterile, but autoclaving in advance is acceptable for Millipore Sterifil Filtration System.

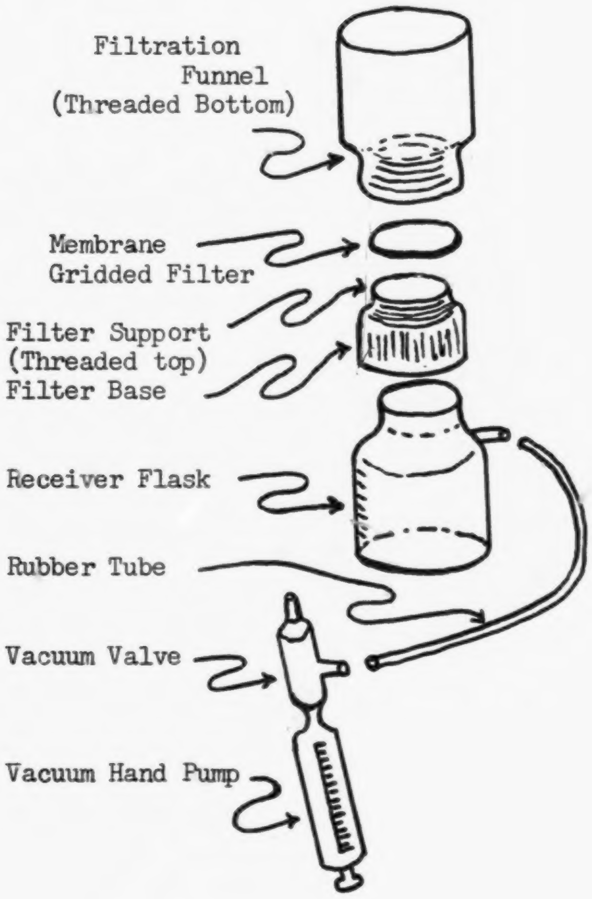

Filtration Funnel (Threaded Bottom)
Membrane Gridded Filter
Filter Support (Threaded top)
Filter Base
Receiver Flask
Rubber Tube
Vacuum Valve
Vacuum Hand Pump

Fig. B-1

Procedure:

1) Set up a boiling water bath by placing a large, wide-mouthed container, containing distilled water, on a stand above a gas burner.

2) Disinfect a laboratory table surface by swabbing it with alcohol. Allow the surface to dry before proceeding. Also swab the bottoms of apparatus to be placed on the table.

3) On the work surface, assemble the funnel unit and receiver flask and connect it to the vacuum system. (Fig. B-1).

4) Set out the petri dishes (raised-lettered side down) and collection bottles.

5) Pour about 20 ml of methanol or ethanol into a small flask and place forceps into the solution. Before using the forceps, they should always be placed briefly in a direct flame from a burner or alcohol lamp to burn off the excess alcohol. Allow them to cool slightly before touching the highly flammable membrane filter.

6) Immerse the filtration funnel and base in the boiling water bath for three minutes. After removing them from the water, attach them to the receiver flask. Loosen the funnel to allow placement of the membrane filter.

7) Using flamed forceps, remove a sterile membrane from

a sealed package. Discard the blue wax packaging disks and reseal the filter envelope. Place the membrane, grid-side-up, over the porous plate of the filter support on the filtration apparatus. Carefully place the funnel over the filter base and lock it in place.

8) Pour 20 to 30 ml of sterile buffered water into the funnel. Check for leakage around the funnel base. (If any occurs, repeat steps 7 & 8). Leave the buffer solution in the funnel.
9) Shake the prepared sample thoroughly and, using the highest dilution first, pipet the predetermined volume (Procedure e) into the buffer solution in the funnel. (Be sure the pipet is sterilized). If more than 20 ml of the sample are to be filtered, a sterile graduated cylinder may be used in lieu of the pipet.
10) Reduce the pressure in the receiver flask by creating a partial vacuum in it. Use either a hand pump (e.g. Millipore Vacuum System) or an electric pump.
11) Rinse the funnel by filtering three volumes of 20 to 30 ml of sterile buffered water through the membrane.
12) Loosen the filtration funnel. Remove the cover of a petri dish. Remove the filter membrane from the filter support with flamed forceps. Place the filter membrane, grid-side-up, on the medium in the petri dish, using a rolling motion to avoid trapping any air.

Replace the lid on the dish and label it on the bottom, identifying the sample and the filtration volumme.

13) Before preparing the next membrane, sterilize the forceps by putting them into the alcohol. Do not forget to flame them. (The rinse, with the buffer solution were sufficient to clean the funnel). Starting with step 7, repeat the procedures for the remaing sample volumes,

Note: The buffer rinses (Step 11) clean the funnel sufficiently for all subsequent filtration unless analyzing water samples for drinking purposes.

g. Incubation

As pointed out in Preparation of Media, bacteria need culture mediums to grow well. The bacteria also need warmth, moisture, and darkness to grow rapidly. Therefore, the petri dishes containing the bacteria are placed in an incubator to assure proper conditions.

Procedure:

1) Incubation of total coliforms.

  a) After preparation, invert the petri dishes containing total coliform cultures and place them in a standard incubator for 24 hours at 35 ± 0.5°C.

Note: The humidity within the incubator must approach 100%; however, when tightly sealed plastic petri dishes are used, a portion of the broth evaporates, raising the humidity within the dish itself to 100% and adjustment of the humidity outside the dishes is not necessary. If dish covers are loose fitting, the humidity can be maintained by placing a vegetable crisper containing wet towels in the incubator. The dishes are then placed on top of the towels and covered with the crisper's lid.

2) Incubating Fecal Coliform Cultures

   a) After preparation, invert the petri dishes containing fecal coliform cultures and place them in waterproof plastic bags (3 to 6 dishes per bag).

   b) Submerge the bags in waterbath incubator and incubate at 44.5 ± 0.5°C.

Note: The temperature of the waterbath is critical. Above 45.0°C. counts drop rapidly. Below 44.0°C. specificity is lost. Therefore no more than twenty minutes should elapse between filtration and incubation to prevent non-fecal coliform colonies from developing at lower temperatures. Submergence in waterproof plastic bags reduces the temperature equilibration time considerably.

3) Incubating Fecal Streptococcus Cultures

a) After innoculation, invert the petri dishes containing fecal streptococcus cultures. Place them in a standard incubator for 48 hours at 35 ± 0.5°C.

h. Counting Techniques.

If all the previous steps were carefully followed, bacterial colonies should now be visible for counting. The results of the count allow us to determine whether the water source is polluted and, if so, how badly.

Procedure:

1) Counting

a) Place the petri dish to be counted under the microscope after removing the lid. Lighting for the counts must be from fluorescent light source as close to directly above the petri dish as possible, so that the image of the light source is reflected off the colony surfaces into the microscope.

b) Count colonies in an orderly back-and-forth sweep from top to bottom of the filter, using grids as channels. Be sure to avoid mixing any colonies or counting any colonies twice simply because they are in contact with a grid-line. Count all colonies individually. Even if two or more are in contact, almost invariably, they show a fine line of contact. Other individual colonies may have grown to unusual shapes because of particles or fibres that may have found their way onto the filter membrane. A hand tally is convenient for counting the colonies.

Note: In dishes of total coliform colonies, the coliform colonies demonstrate a greenish metallic luster or "sheen," which may cover the entire surface of the colony or may appear only in the center of the colony. (Any amount of sheen production denotes a coliform colony). Non-coliform colonies are lighter and do not show this "sheen" even though they may be shiny. In the fecal coliform dishes, the fecal coliform colonies are blue and all other colonies are cream colored (any amount of blue is positive). In fecal streptococcus the colonies have a reddish hue.

(2) Calculations:

The count from your membrane must be adjusted for the diluting you did to the sample and the volume filtered. Results should be in coliform per 100 ml:

Number of Coliform/100 ml

$$= \frac{\text{Number of colonies}}{\text{Vol. of filtration sample}} \times 100$$

For your calculations use the petri dish from the dilution that gives a direct count between 20 and 80. If there are too many colonies on all three dishes, the number is recorded as "t. N. T. C." (too numerous to count). The following shows sample data and calculation:

Sample	Dish #1	Dish #2	Dish #3
No. of coliform	TNTC	39	7
Dilution	1:100	1:10,000	1:1,000,000
Volume filtered	20 ml	20 ml	20 ml

(Dish #2 is used for the calculation because the number of colonies was between 20 and 80).

Number of coliform/100 ml

$$= \frac{39}{20x\ 1/10000} \times 100 = 1{,}950{,}000/100\text{ml}$$

i. Disposal of Cultures.

Cultures, whether on filters or in any other medium should be handled with the utmost care, as if they were all potentially dangerous. When you have completed the experiment and observed the results, the cultures should be destroyed or deactivated, and the petri dishes resterilized. This can be accomplished by the following procedures.

Procedure:

1) Using forceps, carefully remove the petri dish covers and place both covers and dishes into a large beaker or pan containing liquid household bleach for 10 minutes. Unless membranes are to be preserved or reused, they should also be soaked in the bleach.

2) If membranes are to be reused, they should be soaked in ethanol to destroy the colonies. Then sterilization should be completed according to Section a.

3) Membranes may be preserved with colonies by drying on a paper towel. They may even be reconstituted with distilled water for later demonstrations.

5. Bibliography and References

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b. Water Quality Criteria, Federal Water Pollution Control Administration, Washington, D.C. (1968). Summarizes FWPCA recommendations for water classification categories and criteria, and serves as a valuable aid in the

interpretation of test results.

c. McKee, J. E., Wolf, H.W., Water Quality Criteria, 2nd edition, California State Water Quality Control Board, Publ. No. 3-A, Sacramento (1963). A thoroughly documented coverage of nationwide water quality policies, biological effects of pollutants, and judicial action.

d. Pelczar, M.J., Reid, R.D., Microbiology, McGraw-Hill, New York (1965). An elementary microbiology textbook which includes introductions to the taxonomy, biochemistry, cultivation, control and ecological role of microorganisms.

e. Microbiological Analysis of Water, Millipore Corp. (1969). A variety of specific techniques for the isolation and identification of bacteria in water samples is presented.

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C. Aquatic Biology

A biological investigation of an aquatic community should lead to an understanding of the extent to which it has been affected by man. In order to obtain this understanding, those doing the investigating must be able to assess the biological effects of pollution, to identify organisms, to understand and employ field and laboratory procedures, and to interpret the data which they collect. The following section contains information which will be useful to those conducting a biological investigation.

1. The basis of the biological evaluation of pollution.

Pollutants may affect aquatic environments in two ways. Indirectly, they may produce modifications such as altering the food chain, changing the average annual temperature, or reducing the concentration of dissolved oxygen. Directly, pollutants may act physically or physiologically on the resident organisms.

Biological effects of pollutants may be studied by field observation, laboratory evaluation, or both. In the field, evaluations are usually based on comparisons with an actual or imaginary unpolluted reference or "control" site. For example the aquatic life downstream from a point of pollution might be compared with that upstream from the source of pollution. Also, the quality of aquatic life in a polluted area may be compared to previous conditions in that area if "pre-pollution" studies had been made.

Likewise, laboratory evaluation almost always involves a comparison, or control, setup. For instance, the bioassay technique involves the exposing of some type of organism to a series of concentrations of some substance for a stated period of time under controlled conditions.

Qualitative and quantitative evaluations may be used to indicate the "health" of aquatic environments. The indicator concept is based on the thought that there must be some organism which is found only in polluted areas. This is true only for certain types of bacteria which are present in the intestines of warm blooded animals. Finding these bacteria demonstrates a strong likelihood that animal excrement is present. Higher forms of life which are pollution-tolerant may also be found in clean water. Therfore, the finding of these organisms does not necessarily indicate pollution. The species composition of an aquatic community is sensitive to environmental conditions and hence to pollution.

Quantative data may refer to an entire aquatic community or only to selected or individual species. Numbers of individuals, quantitiy (biomass), or both may be investigated. Rate of production, food web interrelationships, and energy flow might also be investigated.

2. The identification of aquatic organisms.

Questions usually posed about an organism seen for the first time are "What is it?" and "What is its name?" Because there are over a million and a half kinds (species) of organisms known, a rather elaborate file reference system must be used for naming and classification.

The system of biological nomenclature consists of a series of groupings, or taxa (singular:taxon). Species is the foundation taxon (plural:species). Similar species are grouped into genera (singular: genus), and similar genera are grouped into families. The system continues in a like manner to order, calss, phylum (plural: phyla), and kingdom. Kingdom is thus the broadest, or most inclusive, taxon.

An investigator must make a decision, based upon the purposes for which he wishes to use his data, as to how precisely he wishes to identify the organisms which he observes. For some purposes he might want to know only how many kinds of organisms were present. In this case he could simply designate them as species a, species b, species c, etc. These designations would be based upon careful observations of likenesses and differences of the organisms studied. This type of "classification" would be acceptable for beginning students. If more precision is desired, an investigator would probably make use of an identification key.

The following key to basic types of plankton and small aquatic organisms should enable the student to determine the general kind of organism he is observing. He may then wish to proceed to a more complete key. Identification to species level will usually be very difficult except under the guidance of a taxonomist of recognized competence in the particular taxon in question.

Key To Types of Plankton And Other Aquatic Organisms*

Read each question in turn, refer to the specimen for the answer. If the answer is yes, proceed to the paragraph indicated in the "yes" column: if no, turn to the paragraph number in the "no" column. If you have made a mistake, the "no" column reference may send you back to re-examine some earlier decision.

If the answer is "yes", there may be no number given in the "yes" column, but there will be a name in capital letters which is the name of the group of organisms to which the specimen belongs, and a plate number is cited which illustrates one or more examples.

*This Key was prepared by Dr. H.W. Jackson, Training Program, Federal Water Pollution Control Administration, Cincinnati, Ohio.

	Yes	No
1. Is it necessary to use a microscope to see the organism?	3	2

	Yes	No
2. Is the organism, or a mass of it, some shade of green or brown? (The shape is probably stringy, round or shapeless).	9	13
3. Is the body relatively complex, with many tiny active hairs or other external structures and complicated insides?	11	4
4. Do the cells contain internal bodies (usually green or golden brown) called chloroplasts? (Sometimes these cells are contained inside outer covers which may hide them completely, or partially. Sometimes they have red "eyespots" or long slender hairs called flagellae).	6	5
5. Are the cells without any, or at least with very little visible internal structure? Generally these cells are bluish green in color (especially a mass of them together) and are very minute. If so, they are Blue-Green Algae. See Plates I, II.	--	3
6. Do these tiny plants consist of singe cells or groups of cells which move about by means of one or more long slender hair-like "flagellae"? Red eyespots usually can be seen.*	--	7

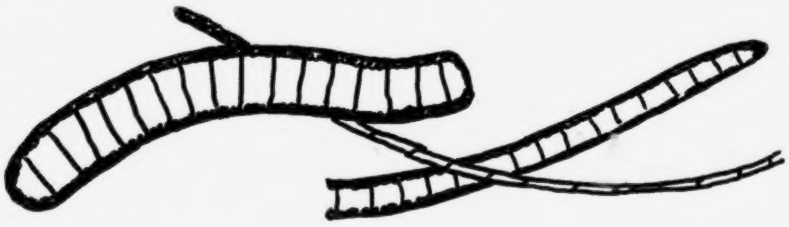
	Yes	No
If so, they are Flagellates. See Plates V, VI. *One kind is large and filled with rust-red granules.		
7. Are they golden brown in color, with a tendency to sharply angular edges? May be cylindrical, thread-like, or boat-shaped. Some may move in a hesitant manner. If so, these are Diatoms. See Plates VII, VIII.	--	8
8. These plants are all green. Do they consist of single cells or small clumps of 2 to 4 cells, but not long strings or filaments? (No flagellae or movement should be observed. If it is, return to 6). These are Coccoid Green Algae. See Plate III.	--	9
9. The following plants (9 and 10) are all filamentous or thread-like, and consist of single cells; cylindrical, barrel-shaped, or roundish, attached end to end. Is green pigment (chlorophyll) contained in various shapes of special bodies within the cells? (chloroplasts) If the mass of		

	Yes	No
filaments appears green or yellow-green to the naked eye, they are Filamentous Green Algae. See Plate IV.	--	10
10. Are the cells of the filament apparently without internal structure (although confused "pseudovacuoles" may sometimes be seen)? Larger oblong cells with heavy walls (heterocysts) or apparently empty cells (akinetes) may occur. Some types with smooth surfaces may move slowly but visibly. Mass of filaments appears some shade of bluish green or red to the naked eye, occasionally very dark. If as above, these are Filamentous Blue-Green Algae. See Plates I, II.	--	4
11. Is the body composed of a single cell or unit? It may be enclosed in a shell or sheath. May bear cilia over all or part of the body; flagellated forms may also be encountered: Protozoa. See Plates IXa and IXb.	--	12
12. Is the non-colored body of the organism composed of many cells, with well organ-		

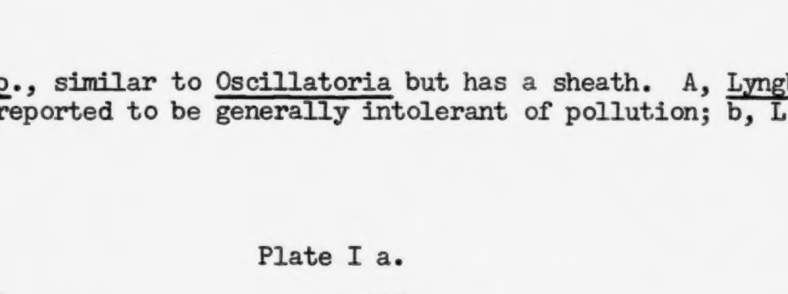
	Yes	No
ized internal structures? There are often one or two crowns of tiny hairs or cilia (which can rarely be seen individually) at one end. One common type crawls like an "inchworm", or "accordion"; others have flattened shells, spines, or other features, but there are no true legs. If as above, this is a Rotifer. See Plate X.	--	13
13. Does the specimen have jointed appendages (joints in the body can also usually be seen), usually with characteristic hairs or setae (may not be extended unless animal is active)?	14	3
14. Is the body completely enclosed in two minute clam-like shells? Jointed legs may be extended from between shells for swimming. These are microcrustaceans, Ostracods. See Plate XII.	--	15
15. Does the elongated, segmented, transparent body (which may range up to approximately ½ inch in length) have a head with two eyes? If so, this is a phantom midge larva, an insect: Chaoborus. See Plate XII.	--	16

	Yes	No
16. Does the organism have a single eye and two shell-like projections that come down on either side of the legs? Eggs may be present in a large pouch inside the upper back part of the shell. This is another microcrustacean, a water flea: Cladocera. See Plate XI.	--	17
17. Is there a single eye, the body relatively cylindrical, no side shells, usually tapering toward the rear? There may be segments (or joint) in the body. Two large front "legs" (actually antennae) are used for locomotion. This is another microcrustacean, a Copepod. See Plate XI.	--	18
18. Is the body similar to the above, but roundish or pear-shaped, smaller, and with no segmentation or joints in the body? There are three pairs of relatively large legs. This is the larva of a copepod called a: Nauplius. See Plate XI.	--	11

Blue-Green Algae Myxophyceae



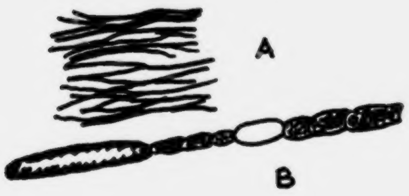
Oscillatoria spp., filaments (trichomes) range from .6 to over 60 µ in diameter. Ubiquitous, pollution tolerant.



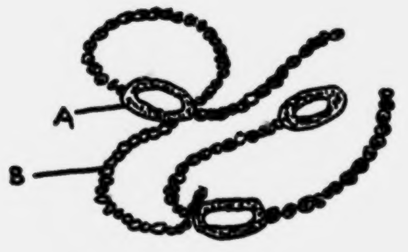
Lyngbia spp., similar to Oscillatoria but has a sheath. A, Lyngbia contorta, reported to be generally intolerant of pollution; b, L. birgei.

Plate I a.

Blue-Green Algae Myxophyceae



Aphanizomenon flos-aquae A, colony; B, filament

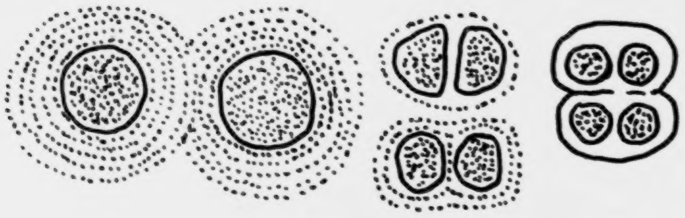


Anabaena flos-aquae A, akinete; B, heterooyst

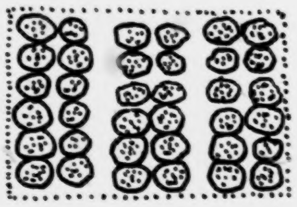
Plate I b.

Some Blue - Green Algae

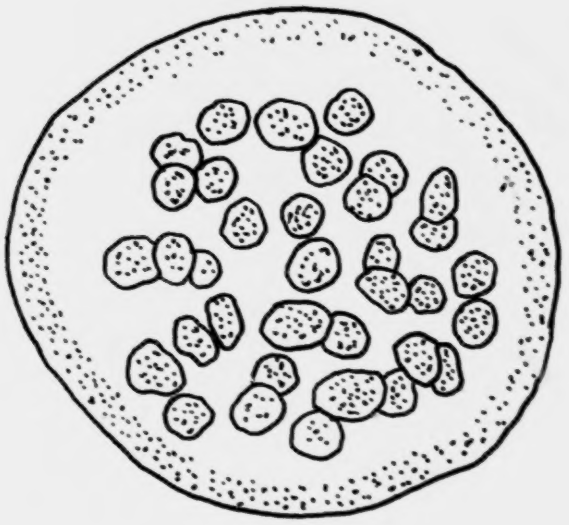
I. Nonfilamentous (coccoid) Blue-Green Algae:



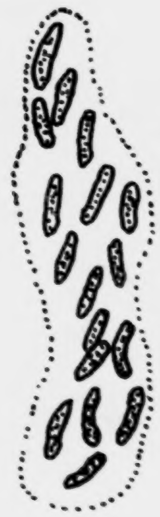
Anacystis (Chroococcus) X600



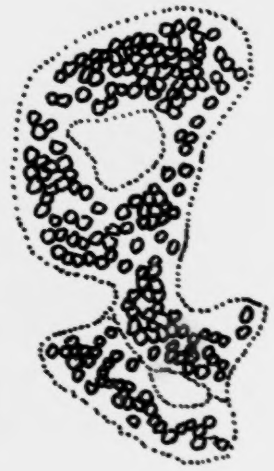
Agmenellum
(Merismopedium) X600



Coccochloris (Gloeocapsa) X600.



Microcystis (X600)

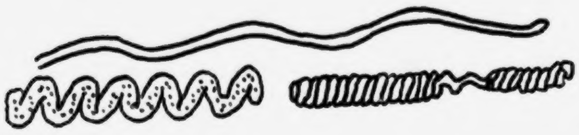


Polycystis
(X825)

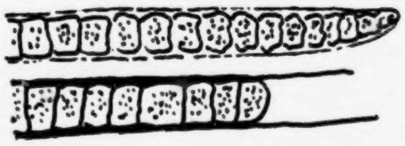
Plate II a.

Some Blue - Green Algae

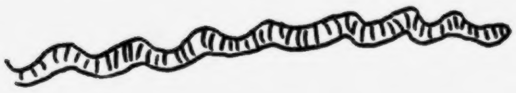
II. Filamentous blue-green algae:



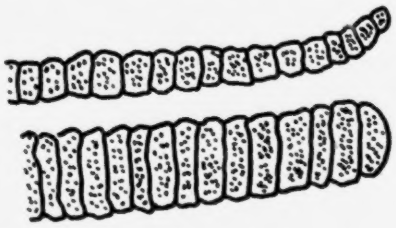
Trichomes of Spirulina. (X600)



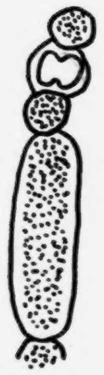
Phormidium (with sheath) (X825)



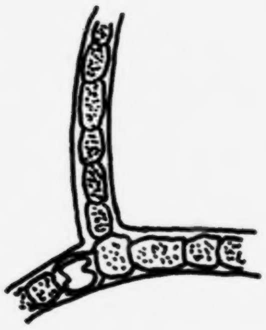
Trichomes of Arthrospira (X600)



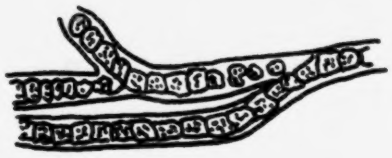
Oscillatoria (without sheath) (X825)



Anabaena (X825)



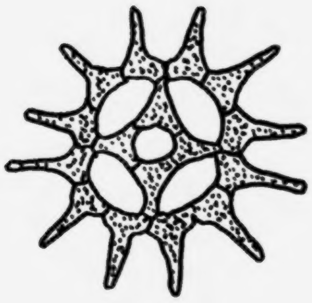
True branching
Hapalosiphon (X375



False branching
Tolypothrix (X375)

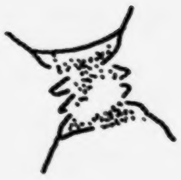
Plate II b.

Non-Motile Green Algae: Coccoid
(Chlorophyceae)

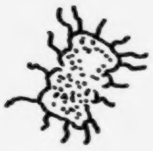


Pediastrum

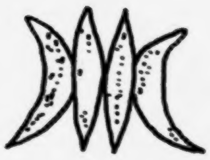
Species of the Genus Scenedesmus



S. caudatus



S. abundans

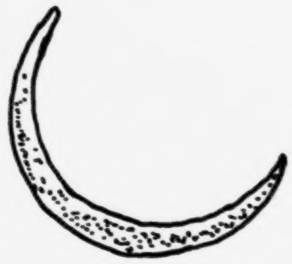


S. dimorphus

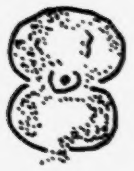
Plate III a.

Non-Motile Green Algae: Coccoid
(Chlorophyceae)

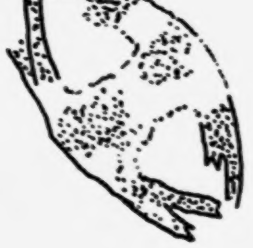
Desmids



Closterium



Cosmarium



Staurastrum

e

Plate III b.

Non-Motile Green Algae

Chlorophyceae

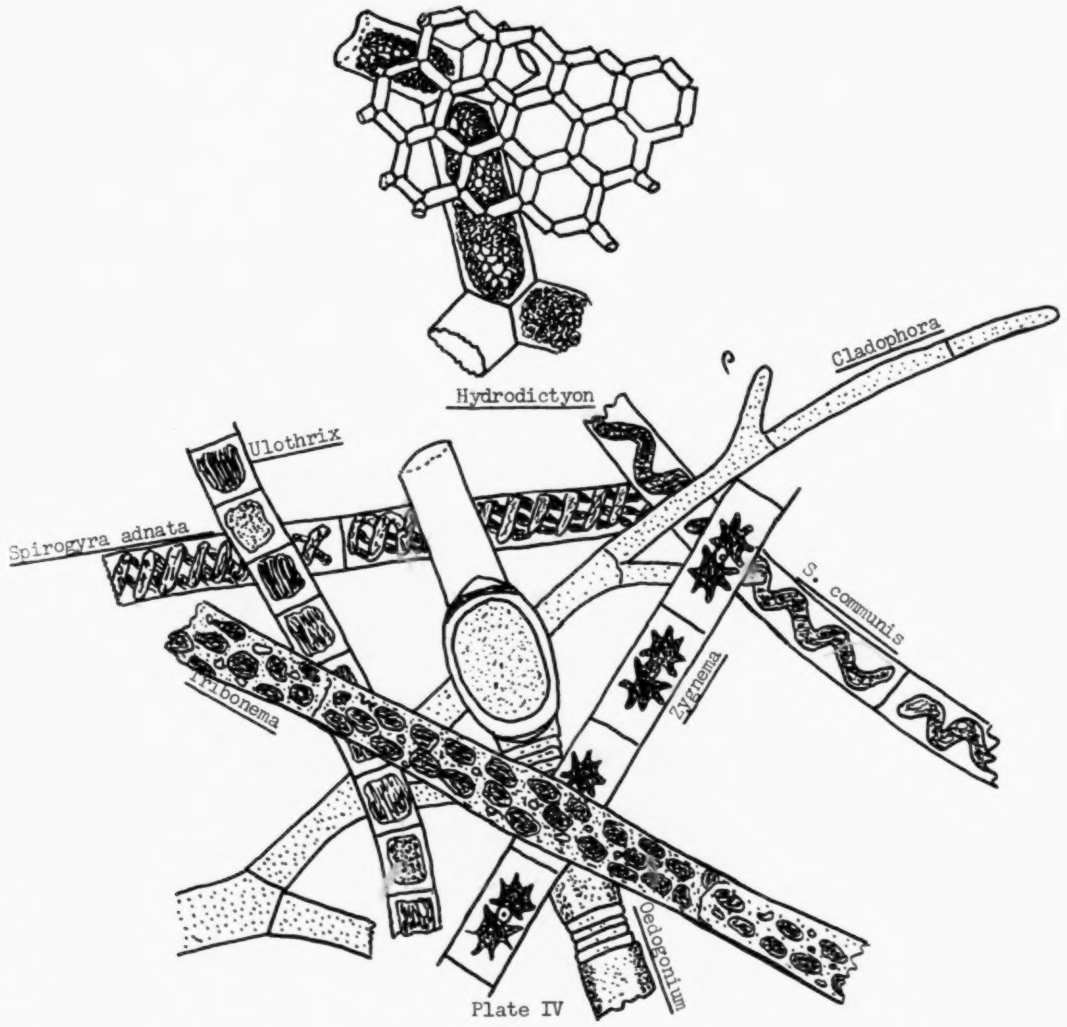
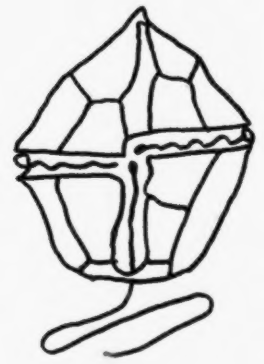
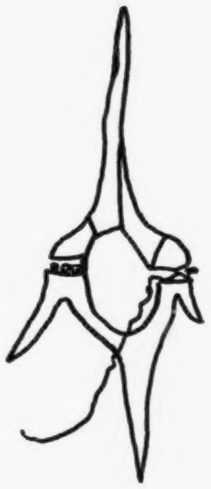

Hydrodictyon
Cladophora
Ulothrix
Spirogyra adnata
S. communis
Zygnema
Tribonema
Oedogonium

Plate IV

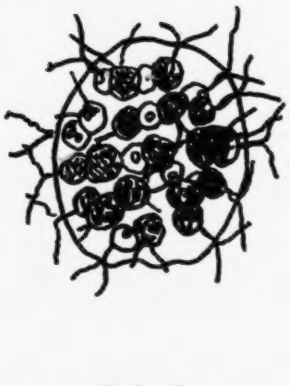
Flagellated Algae



Goniaulax



Ceratium

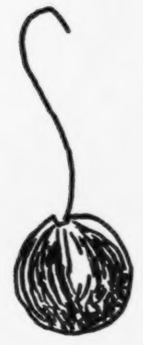


Eudorina

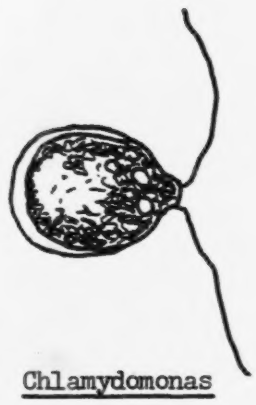
P

Plate V a.

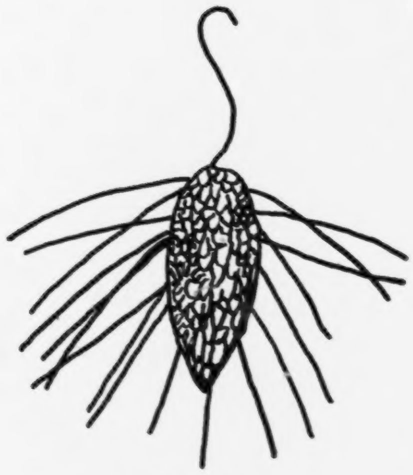
Flagellated Algae



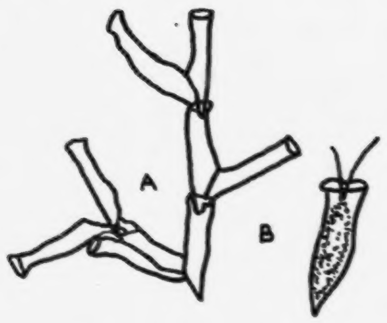
Trachelomonas



Chlamydomonas



Mallomonas

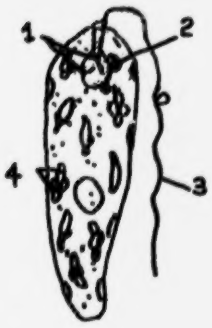


Dinobryon
A, form of colony; B, cell in
lorica.

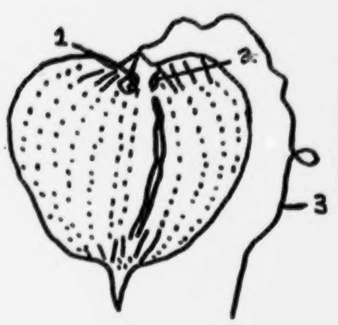
Plate V b.

General Morphology Of Algal Flagellates

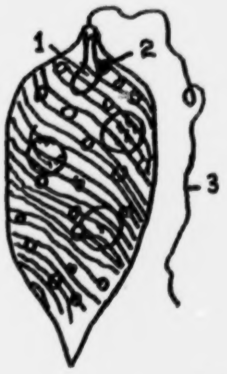
Greens



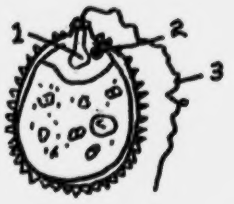
Euglena gracilis



Phacus

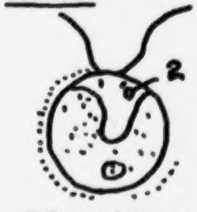


Lepocinclis

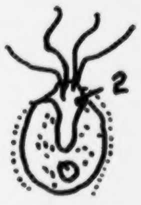


Trachelomonas

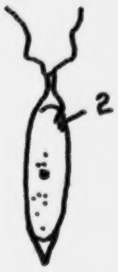
Greens



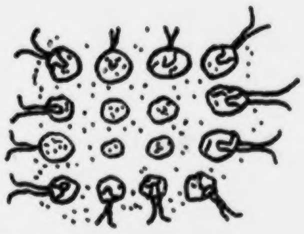
Chlamydomonas



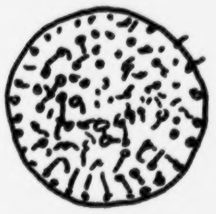
Carteria



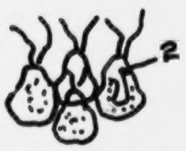
Chlorogonium



Gonium Sociale



Colony of Volvox



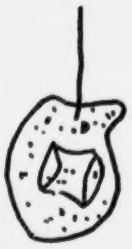
Gonium Pectorale Colony

Pandorina Colony

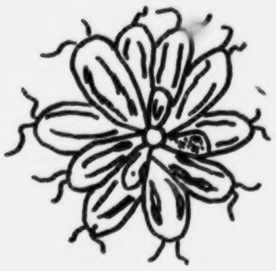
Plate VI a.

General Morphology of Algal Flagellates

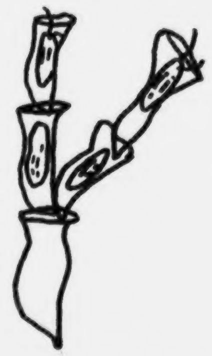
Yellows



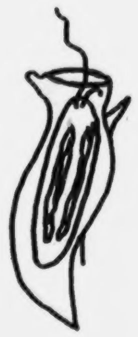
Chromulina



Synura

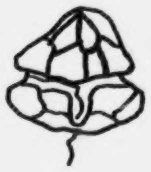


Dinobryon

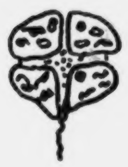


Lorica

Browns



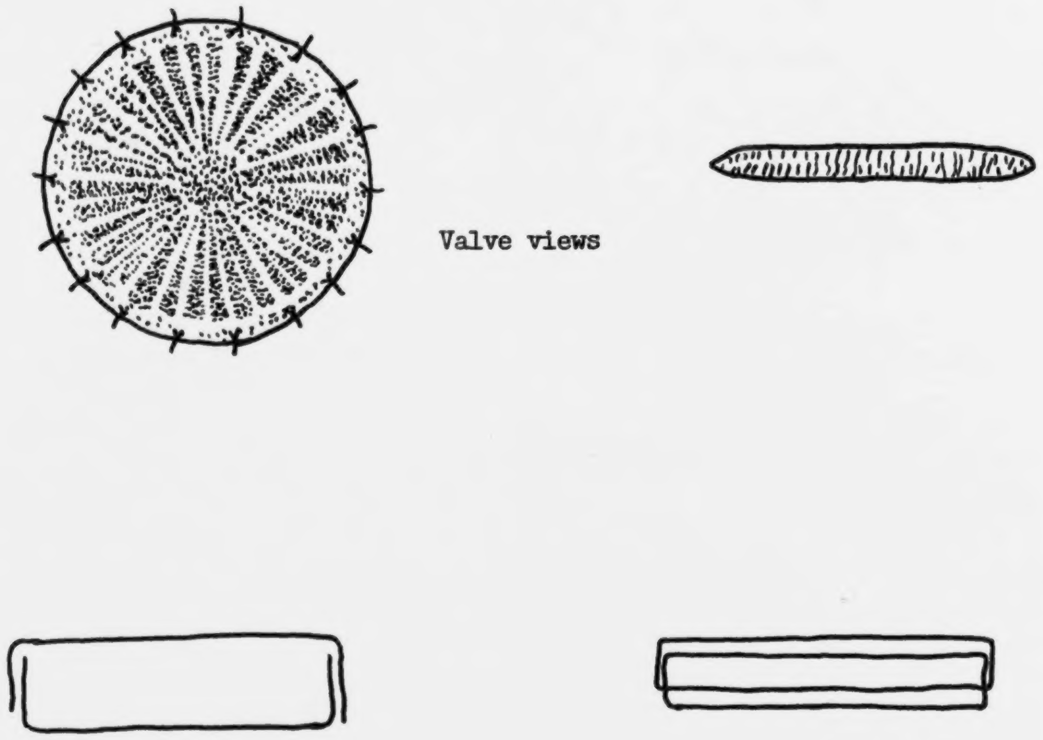
Peridinium



Gymnodinuim

Plate VI b.

Diatoms - Bacillariophyceae



Valve views

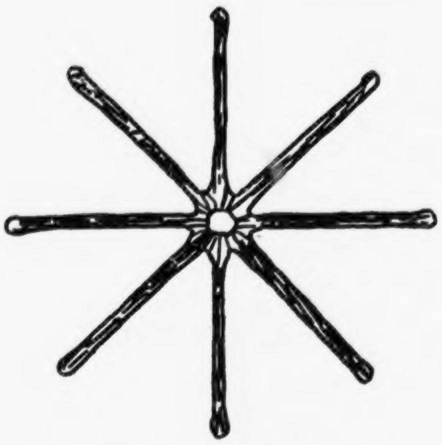
Girdle views, Stylized to show basic diatom structure.

A discoid or central diatom such as Stephanodisous

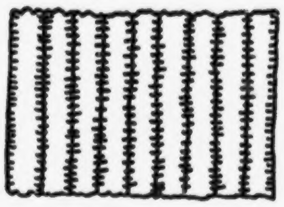
A pennate or navicular datom such as Fragillaria

Plate VII a.

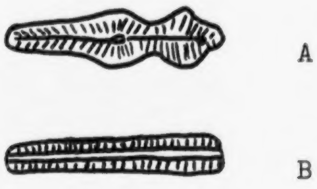
Diatoms - Bacillariophyceae



A colony of Asterionella
(girdle views)



A colony of Fragillaria
(girdle views)



Gomphonoma
A, valve view; B, girdle view.

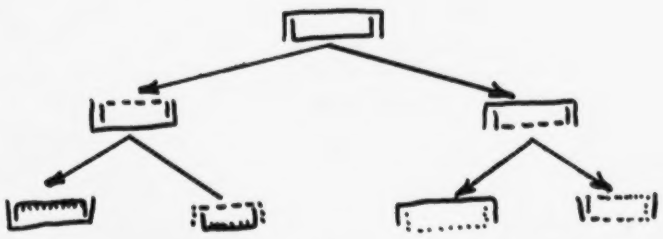
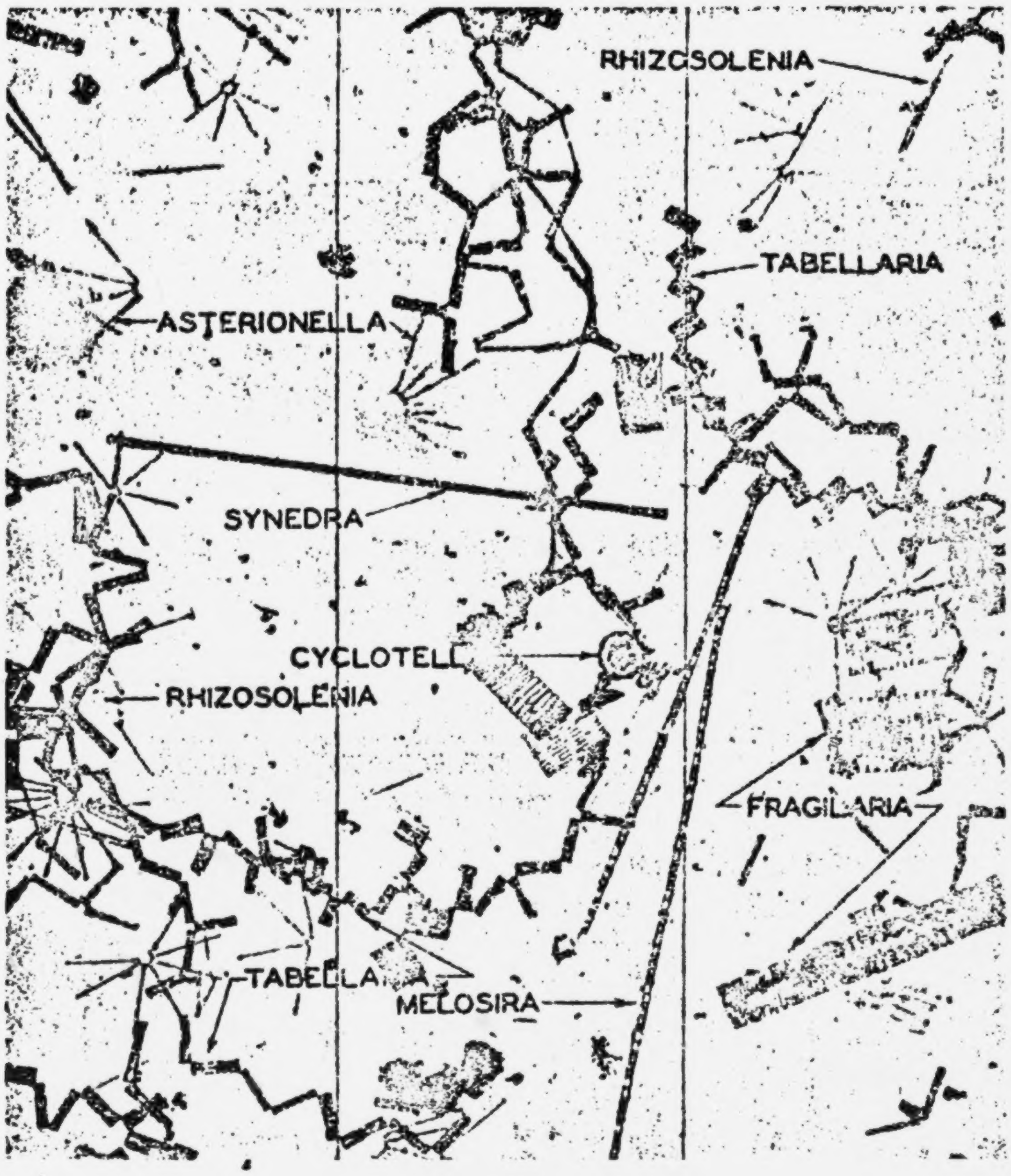


Diagram showing progressive diminution in the size of certain frustules through successive cell generations of a diatom.

Plate VII b.

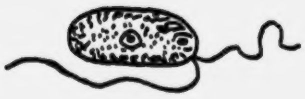

RHIZOSOLENIA
TABELLARIA
ASTERIONELLA
SYNEDRA
CYCLOTELLA
RHIZOSOLENIA
FRAGILARIA
TABELLARIA
MELOSIRA

Photomicrograph of Diatoms

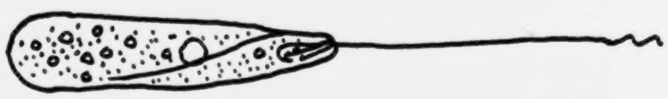
Plate VIII

Phylum Protozoa

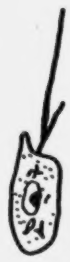
Class Mastigophora, the flagellates



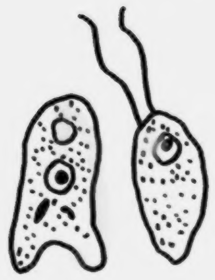
Bodo caudatus
Pollution tolerant
19 µ



Peranema trichophorum
(moderately pollution tolerant)
25 µ

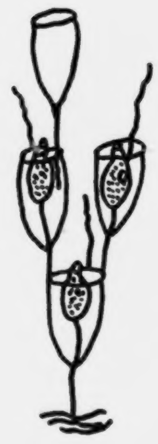


Anthophysis
Pollution tolerant
6 µ



P

Naegleria gruberi
(Pollution tolerant)
10 - 50 µ



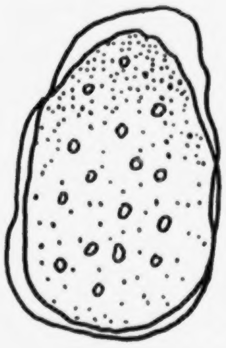
Colony of Poteriodendron
Pollution tolerant, 35 µ

Plate IX a.

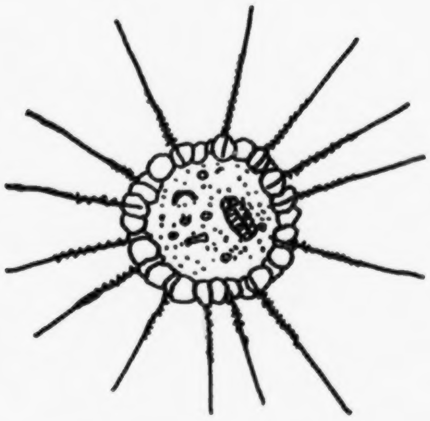
Phylum Protozoa

Class Sarcodina, the amoebas.

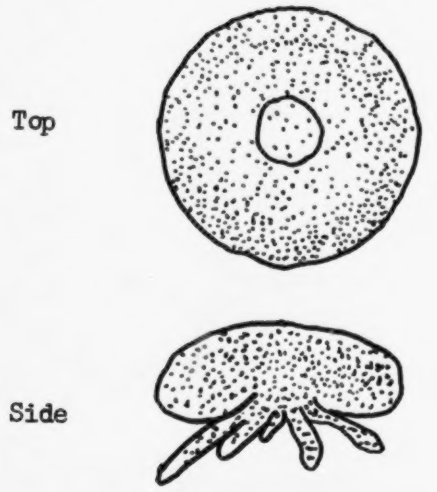
Some forms often found as plankton:



Ameba limicola
45 µ



Actinosphaerium
(Pollution tolerant)
up to 300 µ



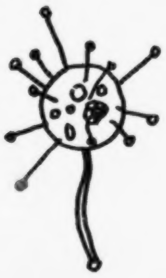
P

Arcella vulgaris
(Pollution tolerant)
40 µ

Plate IX b.

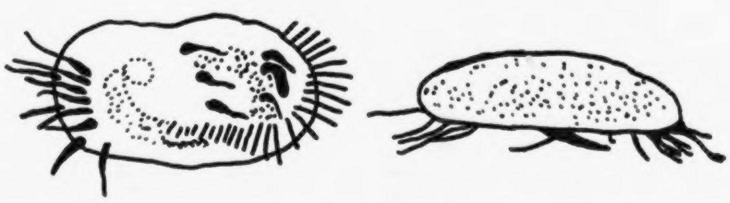
Phylum Protozoa

Class Ciliophora, the ciliates



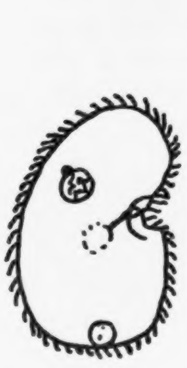
Podophrya, a suctorian ciliate. Pollution tolerant. 20-50 µ

Euplotes
Pollution tolerant, 90 µ

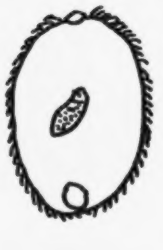


Central View

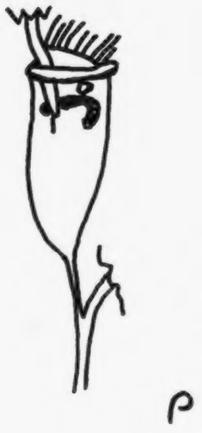
Side View



Colpoda
Pollution tolerant
20-120 µ



Holophrya, reported to be intolerant of pollution, 35 µ



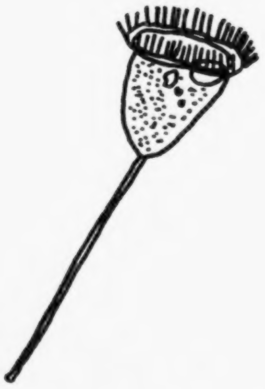
Epistylis, pollution tolerant. Colonies often macroscopic.

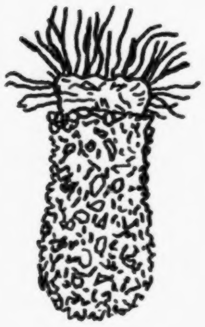
Plate IX c.

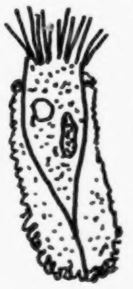
Phylum Protozoa

Class Ciliophora, the ciliates

Some forms often found as plankton:







P

Vorticella

(Pollution tolerant)
Head 75 - 100 µ

Codonella

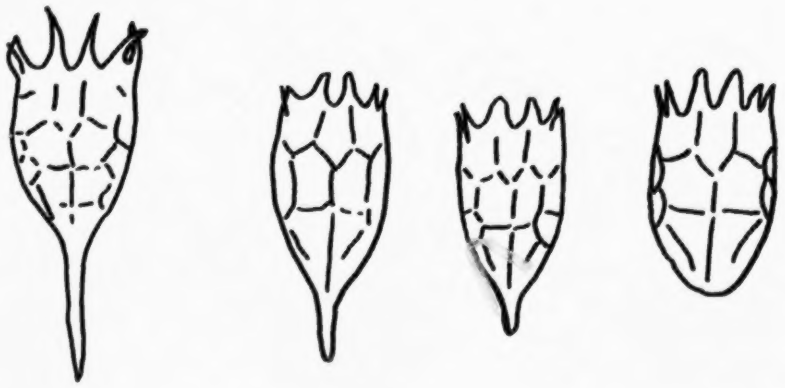
cratera
60 - 70 µ

Tintinnidium

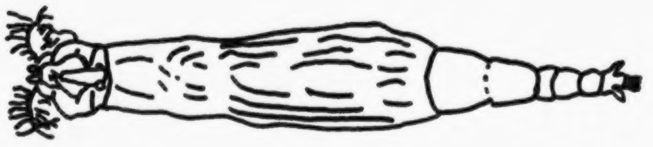
fluviatle
100 - 200 µ

Plate IX d.

Planktonic Rotifers



Various Forms of *Keratella cochlearis*



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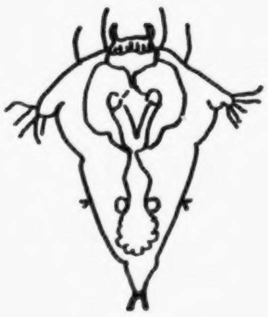
Rotaria Sp

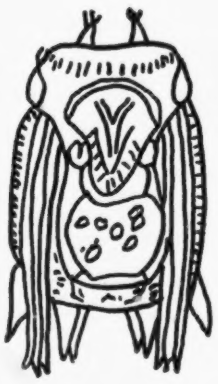
Plate X a.

Planktonic Rotifers

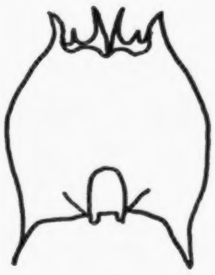
Various Forms of Keratella Cochlearis



Synchaeta pectinata



Polygarthra vulgaris

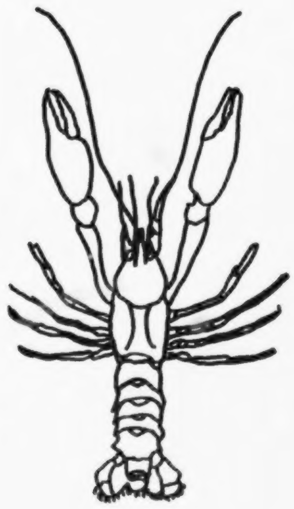


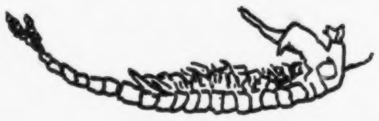
P

Brachionus quadridentata

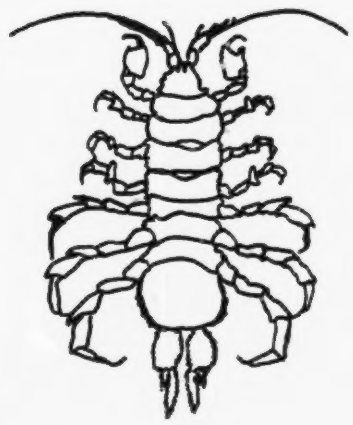
Plate X b.

Class Crustacea



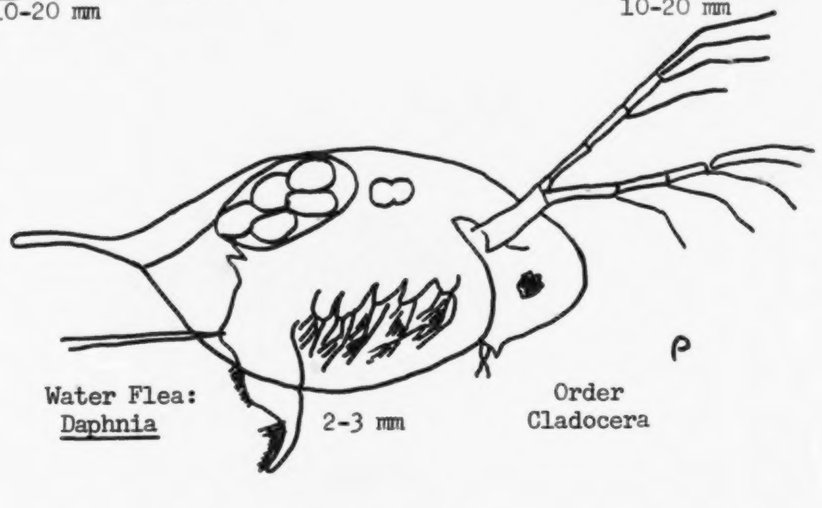


Fairy Shrimp; Eubranchipus, Order Phyllopoda
20-25 mm



Crayfish, or crawdad; Cambarus, Order Deoapoda
10-20 mm

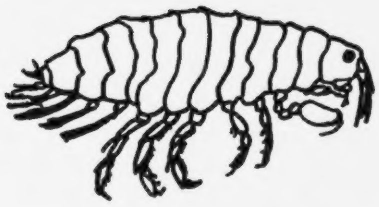
Sow Bug: Asellus, Order Isopoda
10-20 mm



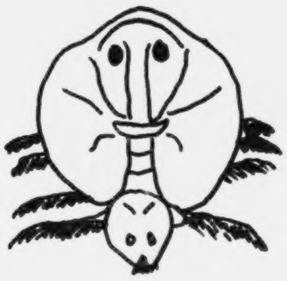
Water Flea: Daphnia
2-3 mm
Order Cladocera

Plate XI a.

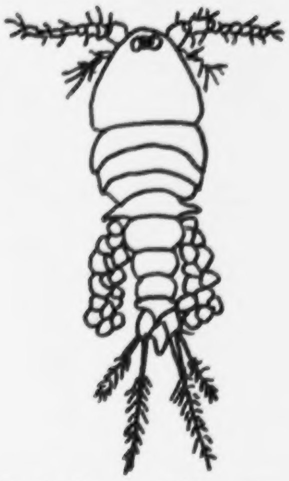
Class Crustacea



Soud: *Hyalella*
Order *Amphipoda*
10-15 mm



Fish Louse, *Argulus*:
a parasitio *Copepod*
5-6 mm

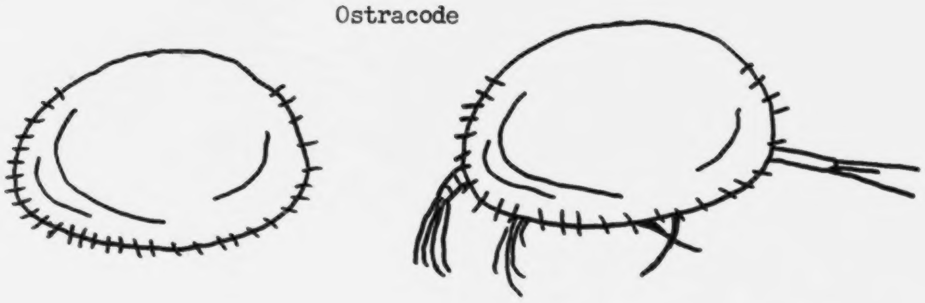


P

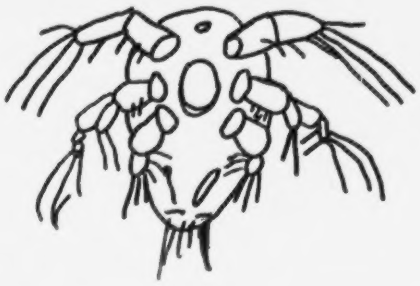
Copepod; *Cyclops*, Order Copopoda
2-3 mm

Plate XI b.

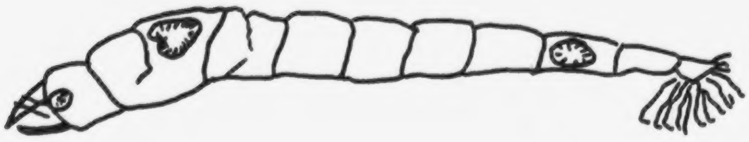
Ostracode



Left: Shell closed Right: Appendages extended



A Nauplius larva of a CopePod



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Chaoborus midge larva

Plate XII

3. Biological field methods

Biological field activities usually consist of two major activities: the collection of specimens and the recording of careful observations. Compact kits of field collecting equipment and materials greatly increase efficiency, especially if the collection site is remote from transportation. All collecting containers should be identified with location, station number, sample number, and the date. Much time may be saved by using data sheets or cards with uniform arrangement for entering the data. The same data sheet may include laboratory or field analysis. Sample data sheets are included at the end of this section. Field notes should be taken in pencil to preserve them in case they get wet.

Observations of the general biological and physical characteristics of the sampling site should be recorded before any sampling is done. Underwater swimming or the use of Scuba may be valuable in certain locations for direct observation and collecting. Underwater and aerial photography may be useful.

Because of the diverse nature of aquatic organisms different methods of collection are used for the various kinds. Aquatic mammals and birds usually require other approaches and are not included. Collection methods for oceanic, estuarine, or freshwater situations are similar. Marine organisms range to larger sizes than those of freshwater. Because of the corrosive nature of sea water, special care should be taken in the design and maintenance of collecting equipment. Site selection and collection schedules for marine sampling are influenced by such factors as tidal currents and salinity distribution rather than river currents, riffles, and pools. Lake collection usually shows less predictable flow patterns. Before going into the field, the investigator should decide on the size range of the organisms to be collected (microscopic, macroscopic) and the kind of organisms (invertebrates, vertebrates, vascular, nonvascular plants) which he will seek.

The following sections explain the collection methods for four groups of aquatic life:

a. Benthos

These are bottom dwelling organisms. They may be attached, crawling, or burrowing forms. Some of the collecting devices are shown in Plates I and II. In most instances, home-made equipment can be substituted for the standard research type. Hand picking of benthic organisms found on rocks, sticks, etc., when picked out of the water, is a fast and much used method for quickly determining what is present and what might be expected in additional samples.

Patches of seaweed and eelgrass and shallow weedy margins are most often studied on a qualitative basis only. The apron net is used for collections in weed beds or other heavy vegetation. It is simply a pointed wire sieve on a long handle with coarse screening on the top to keep out leaves and sticks. Poking it into and then withdrawing it from the weed masses, is the method of operation.

Masses of weeds may be pulled out on the bank (with rakes, grappling hooks, etc.). The benthic organisms can then be observed as they crawl out.

Quantitative estimates of both plants and animals can be made by using a "stove pipe" sampler. This is a hollow tube which is forced down through the weed mass in shallow water and embedded in the bottom. The contents can then be removed and placed into a series of sieves for sorting.

A frame of known dimensions can be placed on the bottom, and the material within is then cropped out. This is especially good for larger plants and large bivalves. It is also useful on sand and mud flats.

Handle-operated samplers such as the Jackson are effective for sampling a variety of bottoms down to the depth of the handles. Such samples are then washed through graded screens to retrieve the organisms.

The Ekman Dredge is a device which is used to collect bottom samples. It should be used in bodiesof water which have muddy or sandy bottoms. It will not work well on gravel or rocky bottoms.

The dredge is lowered into the water until it comes to rest on the bottom. In shall water you can place it on the bottom; for deeper water you lower it on a line or a stick. Next the spring mechanism is tripped. This is done by hand in shallow water and by using the messenger (a device which comes with the dredge) in deep water. After the spring is released, the jaws snap shut and enclose the sample. Finally, bring the dredge to the surface and empty the sample into a plastic bag. Refrigerate or cool the bag if the sample will not be studied within an hour. (Benthic organisms decompose rapidly in warm weather).

Dump the sample out onto the top of a series of graduated mesh, brass screens. The screen with the largest mesh (size of openings) should be on the top and that with the smallest on the bottom. Mesh sizes inbetween should be arranged in order of decreasing mesh size. Flood the sample with water (stirring the sample may be helpful). This procedure will effect two sortings according to size--"soil" particles and macroinvertebrates. Use forceps to collect the macroinvertebrates. Count, identify, mass, and preserve them.

You may want to compute the density and the biomass of the macroinvertebrates. Relate these to other parameters of your study. You may want to study the relationship between "soil" particle size and type and the macroinvertebrates present. An Ekman Dredge can be ordered from Wildlife Supply Co., Saginaw, Michigan. Cost is about $60.00.

The Petersen type, grab without weights, will take satisfactory samples in firm muds, but tends to bury itself in very soft bottoms. It is seldom used in shallow water except as noted below.

The riffle (rift) is one of the most satisfactory habitats for comparing stream conditions at different locations. The hand screen is the simplest and easiest device to use, but the resulting collections are qualitative only. The screen is firmly placed in the stream bed. The upstream bottom is thoroughly disturbed with the feet. The current carries the organisms to the screen. The screen is then lifted, and the contents are dumped into a sorting tray or collecting jar.

The Surber Square Foot Sampler is one of the best quantitative collection devices for rifts. It is firmly planted on the bottom. The stones and other material within the square frame are carefully rubbed by hand to dislodge all benthic organisms. The current carries them into the net. A stiff vegetable brush is often useful, especially if the bottom materials are covered with moss. When bottom materials are picked up which are free from macroinvertebrates the sampling is finished. Before removing the sampler from the water, the bottom should be "fanned" with the hand to kick up any macroinvertebrates which may have fallen straight down rather than being carried into the net. The organisms are then removed from the net and placed in a plastic bag or a collection bottle. To insure a representative sampling, three to five square foot samples should be taken at each location.

A Peterson type grab may be used in deep swift riffles. It is placed on the bottom and worked into place with the feet or with poles. After being closed, it is lifted by pulling on the rope in the usual manner.

A strong medium weight dipnet is the closest approach to a universal collecting tool. Collections are made by sweeping through weeds, over the bottom, or in open water. The handle should be from four to six feet long and about the weight of a garden rake handle. The rim should be made of steel or brass. The size of the rim stock will depend on the size of the rim; it should be strong but not cumbersome. The netting should be the strongest available preferably with about a 1/16 inch mesh. Nets which are too fine plug up easily and cannot be moved quickly through the water. The net must be protected around the rim. This can be done by sewing canvas, leather, or pieces of old innertube around the rim.

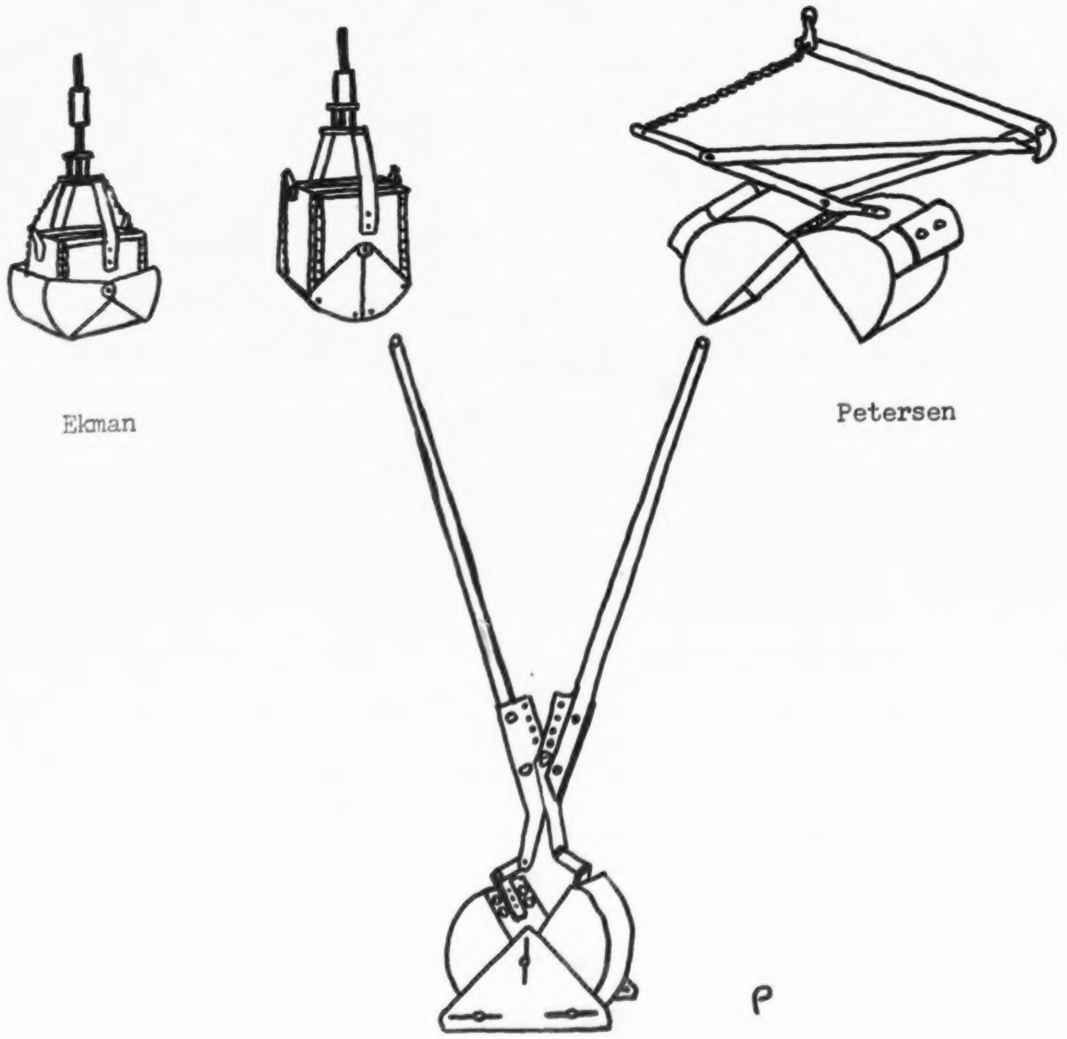
When sampling from vessels a crane or winch is often used. The general ideas described for shallow water often apply also to deeper waters. The Petersen type grab is probably the best all-around sampler for the greatest variety of bottoms at all depths from shoreline down to over 10,000 meters. If hauled by hand, the grab should be fitted with 5/8 or 3/4 inch diameter rope in order to provide adequate hand grip. It is best handled by means of wire ropes and a winch.

Drag dredges or scrapes (Plate I) are often used in marine waters. They have not been used to any great extent in freshwater studies.

Since most biological communities are not evenly distributed, one should routinely take at least two and preferably more samples from any one site.

Artificial substrates (growing surfaces) are also used in studying benthic organisms. When an artificial habitat is provided, it tends to become populated by all available species partial to that type of situation. These devices can be collected and taken to the laboratory for evaluation. They consist of such items as cement plates and panels, wood (especially for burrowing forms), glass

Bottom Grabs



Ekman

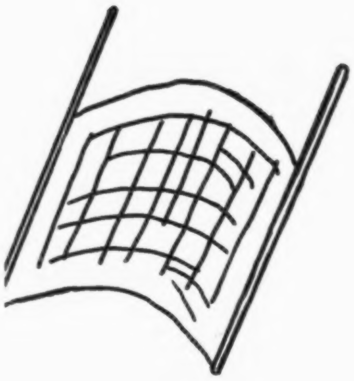
Petersen

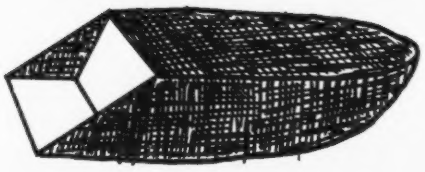
Jackson

P

Plate I

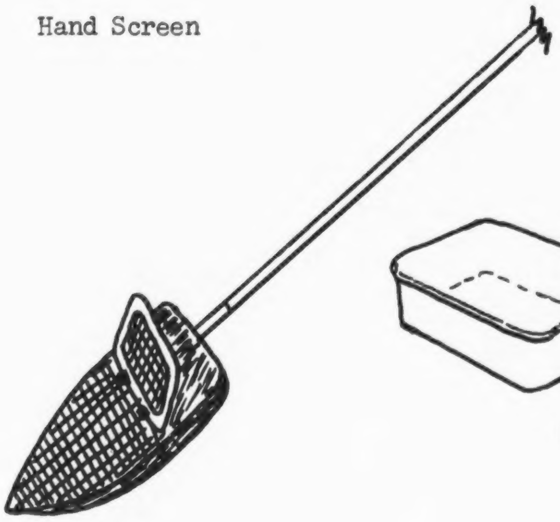
Limnological Equipment

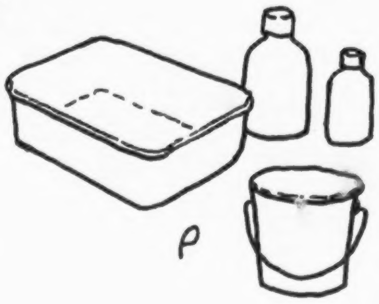




Hand Screen

Surber Sampler





Specimen or
reagent bottles

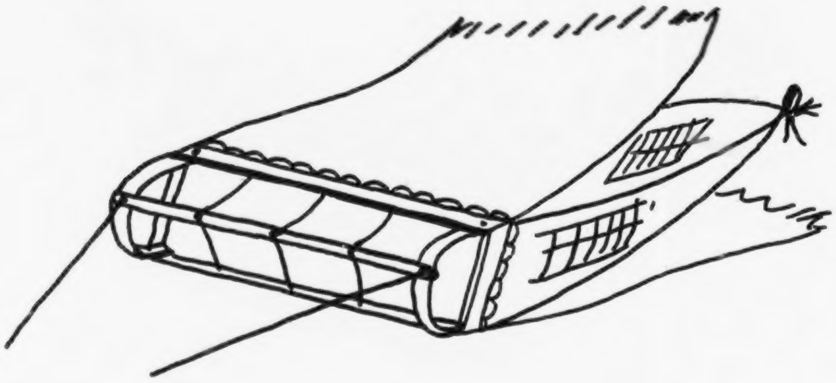
Apron net

Sorting pan

Pail

Plate II

Deep Water Equipment



P

Biological dredge

Plate III

microscope slides (Catherwood diatometer), the Hester-Dendy Sampler, baskets holding natural bottom material, ropes suspended in the water, and sticks thrust into the bottom. The Hester-Dendy Sampler is easily made and lends itself well to student use; therefore it is described in detail below.

The Hester-Dendy Sampler, is used to collect benthic (bottom-dwelling) macroinvertebrates. It can also be used to collect attached algae and some types of datoms. This sampler has .0929 square meter (1 square foot) of exposed surface.

The materials needed are one fourth inch and three eighths inch hardboard, threaded one fourth inch steel rod, and nuts. Cut the one fourth inch hardboard into three inch squares and the three eighths hardboard into one inch squares. Drill three eighths inch holes in the centers of all the squares.

Assemble the sampler by sliding one of the one inch squares on the steel rod, and then add one of the three inch squares. Continue this procedure until you have added eight more of the three inch squares, and nine more of the one inch squares. Now add a nut to each end of the steel rod and tighten. A diagram of a side view of an untightened sampler is shown below.

Tighten the nuts until no space remains between the one inch and the three inch squares and until the squares will stay in place. (An extra three inch square may be added without a spacer if you wish to determine which microorganisms might attach themselves to the non-exposed surfaces).

For any investigation, place all samplers in flowing water or else place all samplers in still waters. (Still waters and flowing waters usually have different benthic populations).

The samplers may be placed on the bottom if it is composed of sand, gravel, or rock. If the bottom is made of mud, suspend the sampler just off the bottom. (If this is not done, the sampler may become covered with mud and a representative benthic sample will not be collected).

If the samplers are placed in highly populated or well used areas, they should be hidden so that they will not be disturbed. In most locations, the samplers should be tied to an overhanging branch or to a root or the bank. Heavy (30 lb. test or higher) monofilament fishing line will be less visible than most kinds of string. In very swift water or in locations where attachment is difficult, the sampler may be attached to a metal rod which has been driven into the bottom of the stream or lake.

Appendix I

Draft

Attempt to show the affects of an effluent on the benthic macroinvertebrates, place samplers upstream and downstream from the point at which the effluent enters. Samplers should be placed on both sides of the stream, and for the larger streams and rivers, they should be placed in the middle too.

After the samplers have been in the water for two weeks or more, they should be collected. Immediately after removing each sampler from the water, place it in a plastic bag and add some surface water from which the sampler came. This will prevent the loss and drying out of the organisms.

If more than an hour will elaspe before you begin to identify the organisms, the plastic bag containing the sampler, should be cooled with ice or refrigerated. This will prevent the organisms from decomposing, which can happen very rapidly especially in hot weather.

Open the plastic bag over a white porcelain tray and remove the water and the sampler. Disassemble the sampler and scrape off any macroinvertebrates which are still attached. (A laboratory spatula works well for the scraping) If large numbers of organisms are present, remove and collect them from one three inch square at a time. This will make them easier to count and identify. (This writer has collected one sampler which had more than 1,300 organisms on it).

The results should be used to compute diversity. The biomass, mass of the life in a specified unit of the environment--here, one square foot, can also be computed. This would give an indication of the productivity of the water.

The organisms may be preserved in alcohol of formalin.

Benthic collections often consist of large amounts of debris. Various procedures may be followed to separate the organisms. This separation may be done by hand picking. It is best done on a white enameled tray using light touch limnological forcepts. Screening is one of the most practical means of separation. The sample may be dumped on the screens, and then separated by pouring water over it to wash away the mud and debris. Another method is to place the sample in a bucket or tub and then add water. The mixture is swirled vigorously, and the supernatant is poured through the screen. The residue should be examined for heavier forms which did not float up. A variation of this method is to pour a salt or sugar solution into the bucket. The mixture is stirred well, and the supernatant is poured through the screen (save it for re-use). The denser-than-water solution effects the separation of organisms from the debris. A solution of 2 ½ lbs of sugar per gallon of water is considered to be optimum for most samples.

Preservation of samples can be achieved by placing them in 95% ethyl alcohol in the field. For prolonged storage they should be placed in 70% solution of ethanol. Formalin is also effective in 3 to 10% solutions of the commercial formulation. Odor and shrinkage problems exist with this preservative. Neutralized formalin eliminates some of the undesirable effects. For short-term preservation, refrigeration and icing are adequate.

b. Periphyton, or Aufwuchs

Periphyton is the collection of organisms attached or clinging to stems and leaves of rooted plants or other surfaces projecting above the bottom of an aquatic system. It consists of algae, fungi, and small animals and protists. Periphyton is sometimes referred to, as the slime forming organisms.

One qualitative method of collection is to scrape the periphyton from surrounding surfaces, and then to place the scrapings in a 4% formaldehyde solution. This can be quantified somewhat by scraping all surface material from a measured area. A more effective quantitative procedure would be to collect the periphyton on an artificial substrate such as glass microscope slides suspended in the water.

By using a microscope and the appropriate identification keys, one can identify the periphyton in the sample.

c. Plankton

Plankton (plancton) is defined as all the microscopic plants, animals, and protists normally swimming or suspended in the open water.

A comprehensive plankton sampling program would involve sampling at weekly or more frequent intervals. A year-long study of this type would provide valuable data which could be used to predict conditions in following years.

Phytoplankton (algae) can be collected at the surface in half-liter bottles. For deeper samples, a Kemmerer, Nansen, or other specialized collector may be used. A plankton net is also useful. Sizes #20 or #25 are commonly used for collecting phytoplankton. Nets concentrate the organisms in the process of collecting; however, the smaller forms will be lost through any net.

Zooplankton (animals & protists) have the ability to swim away from a collection bottle; so they are best captured with nets which are towed at moderately fast speeds. Number 12 nets (operative size 0.119 mm, 125 meshes per inch) or smaller numbered net sizes are commonly used.

The mesh size of the net determines the size of the plankton to be collected.

Both shallow and deep samples are suggested. Shallow samples are taken at a depth of 6 inches to 1 foot. The surface film is also often significant. Deep samples should be taken at as many locations between the surface and the bottom as the study demands. The most complete study would sample the entire water column and would record the kinds of plankton found at each level.

Estuarine plankton should be sampled at different stages of the tide. Since plankton is affected by the forces of winds and currents, a tow is often made at right angles to the direction of wind or current.

Zooplankton tend to collect near the bottom in daylight and to distribute more evenly at night. One method commonly used to get a representative sample is to take an oblique tow from the bottom, to the top of the water column.

Field conditions greatly affect plankton, and they should be carefully noted on the field data card.

Unless the samples will be analyzed within an hour after collection, they should be stabilized in the field. Refrigeration or icing is very helpful, but don't put the ice in the sample. A 5% formalin solution is often used, but it shrinks animals and makes all forms brittle. Lugols solution is a good preservative. Ultra-violet serilization is sometimes used to retard the decomposition of plankton. A good merthiolate preservative has been developed by the FWQA. It has been described by Weber (1968).

d. Nekton

The larger, free swimming animals such as fish, shrimp, and eels are called nekton. They must be collected from the obscure and unlikely areas as well as the obvious in order to insure a representative sample. A check should be made with the local authorities before the sampling is done. The reason for this is that many of the standard techniques are not legal for the layman. Professionally trained workers are very important in this area of investigation; perhaps more important here than in any other area.

The various devices include seines, gill nets, trap nets, traps, trauls, and electrofishing apparatus.

Personal observations by competent personnel and informal **inquiries** with local residents often yield valuable information. The organized creel census yields data on what and how many fish are being caught.

Fish and other nekton are sometimes tagged or branded to trace their movements during migration and at other times. Miniature radio transmitters can be fed or attached, and then the nekton can be tracked over considerable distances. Physiological information can be obtained in this manner also. This is known as telemetry.

e. Sample Data Sheets

Examples of data sheets appear on the following pages. These can be reproduced easily; if desired they can be punched or stapled into notebooks.

LAKE, IMPOUNDMENT, OR ESTUARY SURVEY

Location and General Characteristics

Reporter: ______________

1. Name: ______________________________
   County: ____________ Township: ____________
   Nearest Town: ________________________
   Map agency: ________ Name ________ No. ____
2. Observed nearby land use: ________________
   ____
3. Maximum drawdown or tidal range ____________
4. Depth: Average ________ Maximum ________
5. Area: ____________ Shoreline Length ________
6. Shoreline development*: ________________
7. Watershed size: ________________________
8. Nature and extent of erosion observed: ________
   ____
9. Possible pollution sources: ______________
   ____
10. Study Station No.: ________ Description: ________
    ____
    ____
    ____
    ____
    ____
    ____

$$* \quad \frac{S}{2\sqrt{a\pi}}$$

S = Shoreline length
a = area

L-1

GENERAL MAP

Showing station locations

LAKE, IMPOUNDMENT, OR ESTUARY SURVEY

Present Conditions

Station: ____________ Date: __________ Time: ______

1. Weather
   a. Cloud cover: ________________________________
   b. Wind direction: __________ Velocity: __________
   c. Air Temp: ______________ Precip: __________
   d. Other: ____________________________________
2. Waves
   a. Height: ______ Length: _______ Fetch: _______
   b. Other: ____________________________________
3. Ice, thickness: ____________ Condition: _________
   ____
4. Floating materials: ___________________________
   ____
5. Water Color: _________________________________
6. Nature and origin of color: ______________________
   ____
7. Odor, if distinctive: ___________________________
8. Secchi disc: _________________________________
   or
   Turbidity rod: _______________________________
9. Notes:
   ____
   ____
   ____
   ____
   ____
   ____

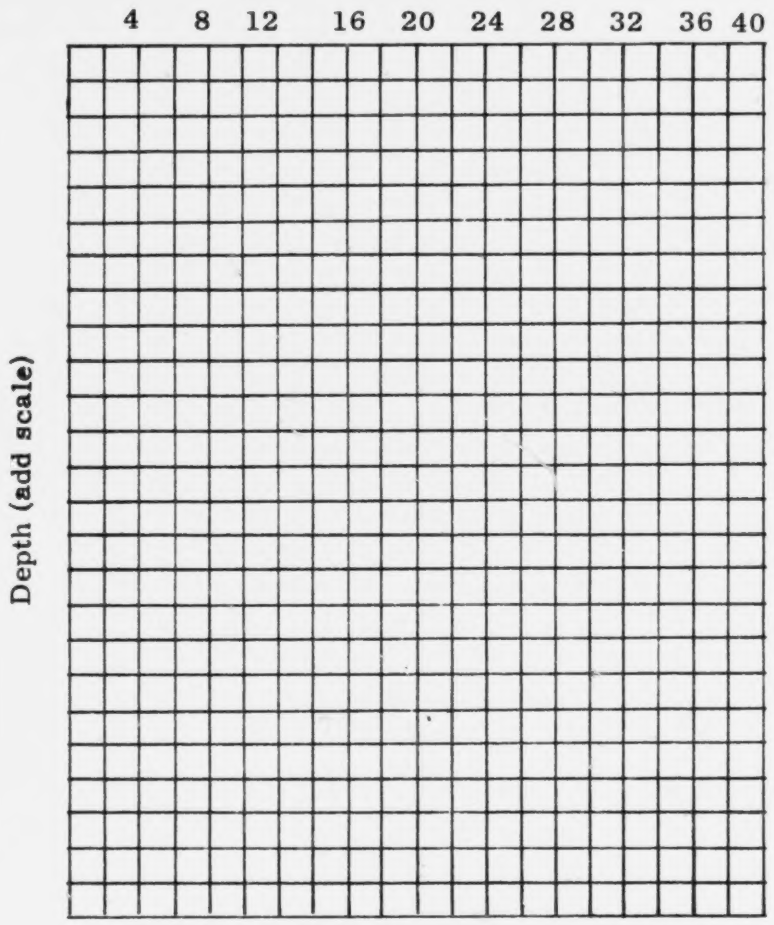
L-2

LAKE, IMPOUNDMENT, OR ESTUARY
SURVEY

Temperature Profile

Station: ________________ Date: __________ Time: _____

Temperature



L-

LAKE, IMPOUNDMENT, OR ESTUARY SURVEY

Physical and Chemical

Station: ____________ Date: ____________ Time: ____________

	Depth	DO mg/l	Other Determinations (note method used)						
a.									
b.									
c.									
d.									
e.									
f.									
g.									
h.									
i.									
j.									
k.									
l.									
m.									
n.									
o.									
p.									

L-3b

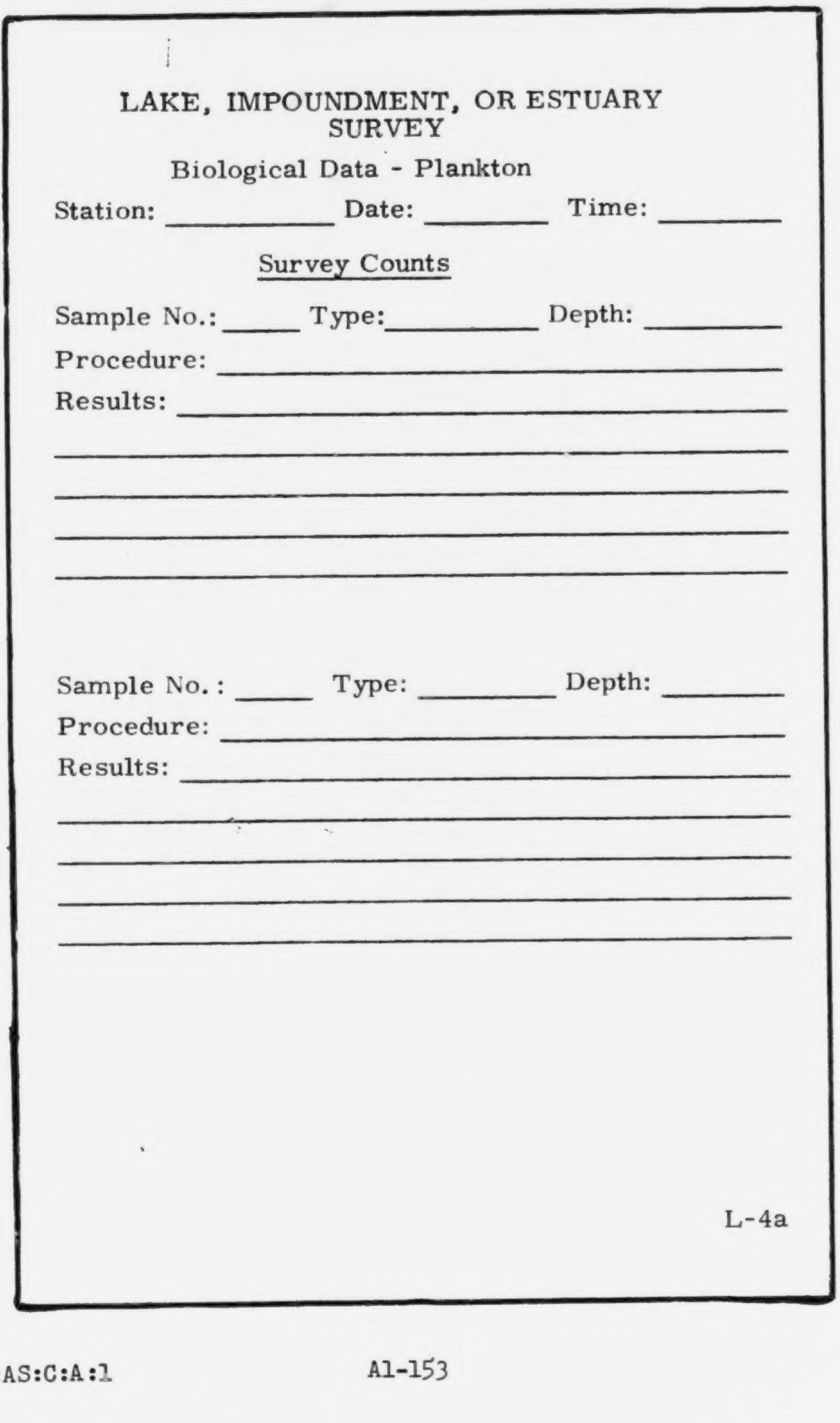
LAKE, IMPOUNDMENT, OR ESTUARY SURVEY

Physical and Chemical

Station: ____________ Date: __________ Time: _________

	Depth	DO mg/l	Other Determinations (note method used)						
a.									
b.									
c.									
d.									
e.									
f.									
g.									
h.									
i.									
j.									
k.									
l.									
m.									
n.									
o.									
p.									

L-



LAKE, IMPOUNDMENT, OR ESTUARY SURVEY

Biological Data - Plankton

Station: __________ Date: ________ Time: ________

Survey Counts

Sample No.: _____ Type: __________ Depth: _________

Procedure: ________________________________

Results: __________________________________

____

____

____

____

Sample No.: _____ Type: _________ Depth: ________

Procedure: ________________________________

Results: __________________________________

____

____

____

____

L-4a

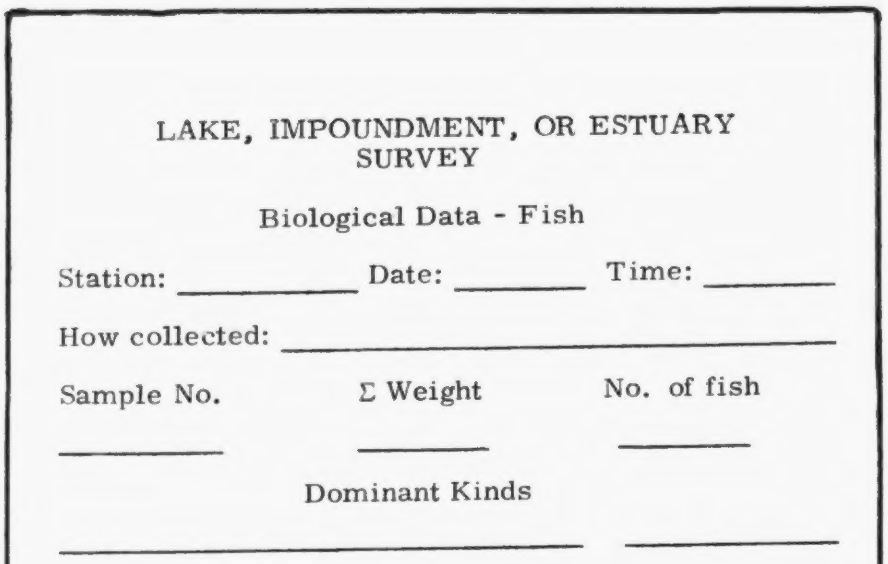
LAKE, IMPOUNDMENT, OR ESTUARY SURVEY

Biological Data - Plankton

Station: _________ Date: _________ Time: _________

Qualitative, Differential, or Proportional Counts

L-4b



LAKE, IMPOUNDMENT, OR ESTUARY SURVEY

Biological Data - Fish

Station: ________ Date: ________ Time: ________

How collected: ____________________

Sample No. ________ Σ Weight ________ No. of fish ________

Dominant Kinds

____________________ ________

____________________ ________

____________________ ________

____________________ ________

Other: ____________________

____

Sample No. ________ Σ Weight ________ No. of fish ________

Dominant Kinds

____________________ ________

____________________ ________

____________________ ________

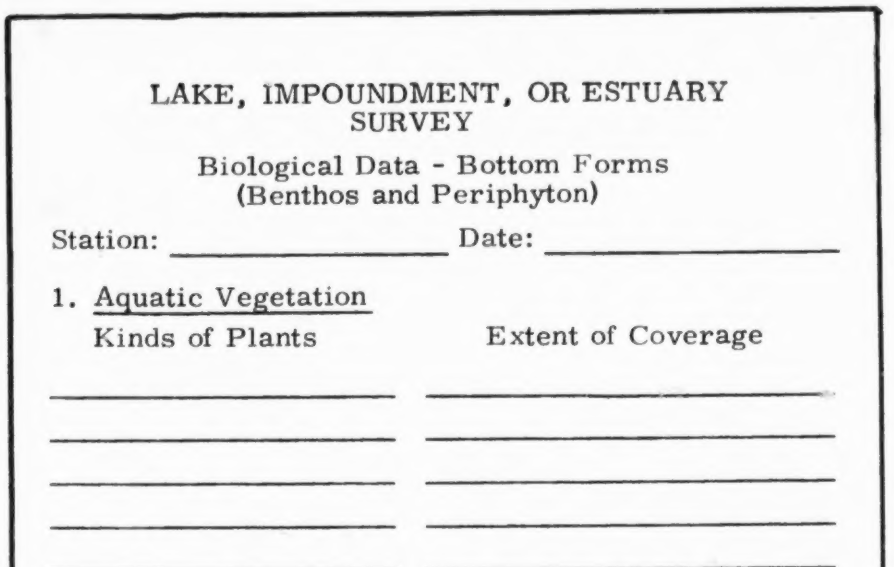
____________________ ________

Other: ____________________

____

L-5

AQUATIC VEGETATION MAP



LAKE, IMPOUNDMENT, OR ESTUARY
SURVEY

Biological Data - Bottom Forms
(Benthos and Periphyton)

Station: ____________ Date: ____________

1. Aquatic Vegetation

Kinds of Plants	Extent of Coverage

How collected: ____________

Nature of bottom: ____________

2. Periphyton

Kinds	Extent of Coverage

Description: ____________

How collected: ____________

Nature of bottom: ____________

3. Attached Algae

Kinds	Extent of Coverage

How collected: ____________

Nature of bottom: ____________

L-6

BOTTOM TYPES MAP

LAKE, IMPOUNDMENT, OR ESTUARY SURVEY

Biological Data - Bottom Forms (Benthos and Periphyton)

Station: ________ Date: ________ Time: ________

Sample No. ________ Unit ________ No. Spp. ________ No. Ind. ________

1. Insects		2. Other Invertebrates	
Kinds	No. or Rel. Abundance*	Kinds	No. or Rel. Abundance*

How collected: ________

Nature of bottom: ________

* + = present a = abundant
c = common d = dominating

L-7

LAKE,IMPOUNDMENT, OR ESTUARY SURVEY

Biological Data - Bottom Forms (Benthos and Periphyton)

Station: ______________ Date: ________ Time: ______

Sample No.	Unit	No. Spp.	No. Ind.

1. Insects		2. Other Invertebrates	
Kinds	No. or Rel. Abundance*	Kinds	No. or Rel. Abundance*

How collected: ______________________________

Nature of bottom: ______________________________

*+ = present a = abundant

c = common d = dominating

L-7

LAKE, IMPOUNDMENT OR ESTUARY SURVEY

Bacteriological Data

Station: __________ Date: __________ Time: __________

How and where collected: ______________________________

____

____

Time collected: ______ a.m. p.m. Temp: __________ °C

Collected by: ______________________________

Tests started ______ a.m. p.m. By: __________________

Tests requested: (check)
- Coliform: __________________
- Fecal Coliform: __________________
- Fecal Streptococcus: __________________

Remarks: ______________________________________

____

____

____

____

____

____

____

____

Test results:
- Coliforms: ______________ 100 ml
- Fecal Coliforms: ______________ 100 ml
- Fecal Streptococci: ______________ 100 ml

Method: Membrane Filter ( )

L-8

NOTES

4. Biological laboratory methods

Living specimens are the most desirable for laboratory analysis. Unfortunately the investigator must often work with preserved specimens. When conducting a comprehensive investigation, a biologist usually collects samples faster than he can analyze them.

After the laboratory data have been recorded, they should be interpreted with reference to the field notes which were taken at the time of sample collection.

a. Benthos

Although some fish (i.e. flounders) are listed as benthic organisms, the usual bottom sample is analyzed for the macroinvertebrates which it contains. After the foreign material has been removed from the sample (see Section 3), the investigator counts, identifies, and determines the mass of the organisms.

A technique commonly used is to pour the sample into a white porcelain tray which has some tap water in it. Laboratory forceps are usually used to remove the organisms. If the sample contains large numbers of organisms, the investigator will find a mechanical hand counter very useful. The organisms should be placed on blotting paper for one minute before the mass determination is made.

If the investigator does not wish to "key out" the organisms, he may simply sort and group on the basis of like appearance. He might sketch and/or describe the different kinds and report something like, "75 individuals of species 1".

b. Periphyton, or Aufwuchs

Direct analysis of the growths while attached to the substrate can be carried out, but must be restricted to the larger organisms. This is because of the difficulty of keeping the material in an acceptable condition under the short working distances of the objective lenses of compound microscopes and because transmitted light is not adequate when the colonial growths are thick or the substrate is opaque.

More often the periphyton is scraped from the substrate and then processed. Aliquots of the sample may be counted using methods frequently employed in plankton analysis. The number of organisms per unit of volume can then be determined.

The total dry weight of the scrapings and the ash-free dry weight (which eliminates inorganic sediments) can be determined and compared. A packed biomass and volume could be determined by centrifugation of the scrapings.
Nutrient analyses serve as indicies of the biomass by

measuring the quantity of nutrient incorporated. Total organic carbon, carbon equivalents (COD), and organic nitrogen determination would be helpful. Phosphorus has limitations because cells can store excess above immediate needs. Chlorophyll and other bio-pigment extractions might be carried out. Other investigations might measure carbon-14 uptake, oxygen production, or respiratory oxygen demand.

Qualitative studies would produce such results as the kinds found, ratios of number of individuals per kind found, and a frequency distribution of varieties found.

Quantitative investigations could yield amounts per unit area, milligrams per square centimeter. Rate studies could determine such things as milligrams per day of biomass accumulation or milligrams of oxygen produced per milligram of growth per hour.

c. Plankton

Microscopic examination is most frequently done in the laboratory to determine the number and kinds of organisms present. Optical equipment need not be elaborate for qualitative studies. If more precision is required such items as a Whipple counting eyepiece, a mechanical stage, and a stage micrometer may be used.

Precision made counting chambers such as Sedgewick-Rafter or Palmer counting cells or haemocytometers are required for quantitative work with liquid mounts. Qualitative "counts" are lists of the kinds of organisms found.

The organisms are observed, and by means of a suitable series of multiplier factors, projected to a number or mass per unit volume. Counting of an unconcentrated sample eliminates manipulation. If the density of organisms is low, more area can be examined or the sample can be concentrated. The concentration of the sample provides more organisms for observation, but this introduces additional errors and takes more time.

Several methods of counting are in general use. The numerical or clump count is regarded as the simplest. The areal standard unit method (Number per unit area)is becoming increasingly popular with waterworks operators. The cubic standard unit method is a logical extension of the areal method, but it has not achieved wide acceptance.

The field count is done by counting and tallying all individuals of each type present in a field of view. A good way to do this is to list the most common types separately, record their counts, and then enumerate the other forms. This is done for five or ten randomly chosen fields. Finally the results are tallied, and the percent of each type is computed.

The five hundred count is done by moving the slide at random and counting and tallying all the types until a total of 500 cells or clumps have been counted. Then the investigator should tally the results and compute the percentage of each type as before.

Sometimes measurements are made by means other than microscopic counts. Settled volume of killed plankton may be measured in an Imhoff cone or a graduated cylinder after a standard length of time. This will evaluate only larger forms. A gravimetric method involves drying at 60° C for 24 hours followed by ashing at 600° C for 30 minutes. This is particularly useful for chemical and radiological analysis.

Chlorophyll can be extracted by filtering, drying for 24 hours, and extraction with methyl alcohol. Evaluation can be made using a colorimeter or chromatographic methods. A membrane filter may be used. The filter can be cleared with immersion oil and organisms can be observed directly after 24 hours, or the collected material can be washed off and observed immediately.

d. Nekton

Population studies are often done with the larger animals. The individuals should be checked for general condition and for the presence of parasites.

As mentioned before, the collection of fish is best done by professionals.

e. Bioassays and Biomonitoring

The bioassay technique may be used on any appropriate organisms from protozoa to fish. In the lab two types of apparatus, static jar and continuous flow, may be employed to provide the various dilutions of the toxicant used.

Static jar tests are containers with a known concentration of substance and organisms. These tests are seldom run for more than one week and are read only in terms of percent survival or kill. This is usually termed "acute toxicity."

The continuous flow apparatus may also be used to measure acute toxicity. This setup allows a solution to flow into the containers at certain time intervals. Continuous flow apparatus is virtually essential for long-term tests at sublethal concentrations. Parameters other than lethal thresholds can then be measured, such as the effect on growth rate and breeding success of a species of fish.

Biomonitoring permits continuous surveillance over the toxicity of an effluent. This technique involves the placing of living organisms in test waters. A common length of time for the test to be run in water pollution, is 96 hours. For the results to be significant, a 50% or greater kill must occur during the 96 hours.

In the laboratory, place ten middle-sized Daphnia in each four ounce bottle. Daphnia magna, commonly called water fleas, are small crustaceans. If they can't be obtained locally, they can be ordered live from a biological supply house. Middle-sized ones are used so that natural mortality due to age, will not lead to incorrect results.

Cover each bottle with nylon cloth having at least 80 squares to the linear inch. If this kind of cloth is not available, two thicknesses of a piece of a nylon stocking will probably be acceptable. The cloth must detain the Daphnia and permit the dissolved substances to diffuse into the bottle. Use rubber bands to fasten the cloth over the opening of the bottle. Place five of these bottles in a six inch square wire container (which can be made from ¼ inch hardware cloth) and place it in the stream. After 96 hours count and record the number of living adults and offspring.

Small (two to three inch) bluegills (Lepomis macrochirus) and/or largemouth bass (Micropterus salmoides) can also be used. These should be fed and acclimated to laboratory conditions for two to four days before being placed in the stream.

The fish can be transported to the bioassay stations in 10-gallon milk containers lined with large plastic bags. If aeration is necessary, use an aquarium pump (which can be run off an inverter). The inverter changes 12 volts into 110 volts.

At each station place 10 bluegills or 10 largemouth bass in a Gee's galvanized, quarter-in-square wire minnow trap (manufactured by Cuba Specialty Mfg., Co., Houghton, New York). Close the hold in each end of the minnow trap with a cork or a rubber stopper. This will prevent predators, such as eels, from getting into the trap.

Slowly acclimate the fish to the temperature of the stream. This can be done by putting the fish into a plastic bag (with water from the milk can) and then placing the plastic bag into the stream or else by adding stream water--small amounts at a time--to the plastic bag.

After adding the fish to the trap, place it in one or two feet of water of very low velocity. If slow-moving water cannot be found, place in on the downstream side of a large rock or other obstruction.

Transfer the living fish from the trap to a plastic bag (after 96 hours). Note the conditions of the surviving fish. Look for vitality or a lack of it. Observe the fins-some chemical effluents cause them to deteriorate. Record the number of dead fish and the number and conditions of each of the surviving fish.

If these tests are done in highly populated or well used areas you must carefully hide the bottles and traps. If this is not done they will be disturbed or taken.

Be sure that you do not subject the Daphnia or the fish to temperature shock at the time of placing them in the stream. Daphnia can stand a rapid temperature change of only one to two degrees farenheit and the fish can stand a rapid change of only two to four degrees farenheit.

f. Diversity Indexes

The statistical analysis of some kinds of biological data may be done by computing the diversity index. Generally speaking, the greater the diversity, the healthier the biotic community. There is presently no one method of computing this index which is universally accepted by the professionals. They range from simple ones to ones that are best calculated by computers.

The sequential diversity index is explained below. An exercise is included to show the use of this index in the activities section (Ch. 3) of this document. Others may be found in some of the references listed at the end of this section.

The sequential diversity index is found by dividing the number of runs by the number of specimens as shown below:

$$\text{Diversity index} = \frac{\text{number of runs}}{\text{number of specimens}}$$

A run is a set of like individuals picked up or observed respectively. A run ends when an individual of another kind is found. Therefore, a run can consist of only one individual. The specimen being observed need only be compared with the previous one. If it appears to be similar, it is part of the same run; if not, it is part of a new run. The more runs for a given number of specimens, the greater the diversity.

Suppose that an investigator is observing cellular algae on a haemocytometer. As he scans the field of view from left to right, he observes the following: first, five cells of the same kind which he calls type S; second, ten cells of another kind which he calls type I; third, five cells of type S; and finally one cell of type U. At this point the investigator has four runs and eleven specimens. The usual procedure would be to continue in manner until 200 specimens had been counted, and then the diversity index would be computed.

Macroinvertebrates may be poured out onto a grid of some sort and treated in the same manner. Alternatively, they may be sorted according to kind. For example, there might have been 80 green, worm-like specimens, 40 snails, and 80 leeches. Then the green, worm-like specimens would be represented by numbers 1-80, the snails would be 81-120, and the leeches 121-200. Numbered slips of paper would then be randomly drawn to determine the number of runs.

If more than 200 macroinvertebrates are in a sample, randomly pick and sort until 200 specimens have been removed. The remaining organisms can be discarded. (If results from different locations are to be meaningfully compared, the diversity indexes should be computed for the same number of specimens.)

5. The Significance and Interpretation of Biological Data

The interpretation of data is a time-consuming process. Biological variability often confuses the beginner. One of the commonest examples of this is that a few individuals of the same species will respond differently than the others to environmental conditions which are apparently the same. One should be aware of exceptions, but he should not be disturbed if he cannot explain them.

In order to get the most complete picture of an aquatic system, data from as many parameters as possible should be studied. As a matter of fact, data from a single parameter may mean nothing by themselves. Finding inter-relationships among the various parameters and relating these to the whole are extremely important.

Care should be exercised to be sure that the data were collected from a representative sample. Following are a series of tables which should aid in the interpretation of data. The information contained in them is not absolute; it should be used only as a guide.

Warning

If the relationships do not seem to apply to your investigation, other factors (perhaps requiring equipment not available to you) may be involved. Rather than risk publicizing an unwarranted conclusion, seek the advice of a professional.

Cross-check related observations in different tables. For example, if low D O is detected under chemical, check turbidity under physical and severe organic pollution under biological.

The interpretation of phrases such as "great variety", "less variety" and "high coliform count" may pose a problem for beginners. Most states have developed water quality standards which will be helpful in the interpretation of bacterial and some chemical data. If professional macroinvertebrated data (or assistance) are not available to the beginning investigator, he will have to collect extensive data himself, and then make his own interpretations.

Table 1 - C - 1 Biological Observations

In Case of:	Look for or Expect:
1. Using Sequential Diversity Index (SDI)	
Great variety with few of each kind.	Clean Water
Less variety with great abundance	Overly enriched (Moderate organic pollution)
One or two kinds only, with very great abundance	Severe organic pollution
2. The qualitative interpretation of freshwater macroinvertebrates.	

In Case of:	Look for or Expect:
Mayfly, caddisfly, and stonefly larvae, plus a considerable variety of other macroinvertebrates.	Clean Water
Pollution tolerant types predominate, although a few less tolerant or unknown forms may be present.	Moderate organic pollution Suggestion: 1. Confirm with coliform and other tests.
One or two pollution tolerant types only, often present in overwhelming abundance	Severe organic pollution Suggestion: Same as above.
No macroinvertebrates at all, little or no plant life.	Toxic pollution Suggestion: Same.

3. Quantitative Interpretation of freshwater invertebrates from riffle areas. Note: Carefully review weather records for the preceding few weeks. A severe flood could invalidate the following interpretations.

0 - 2 grams, per feet^2 (blotted live weight)	Unproductive probably clean stream. Suggestion: Check for toxicity.
3 - 5 grams per ft.^{2}	Normally productive. Proba-

In Case of:	Look for or Expect:
	bly well balanced stream community.
Over 6 grams per ft.^{2}	A. Highly productive stream, probably organically enriched (polluted). B. Note: These relative values will differ in different parts of the country. C. Check the SDI.
4. Productivity measurements	
Water at sampling site seems to be underproductive or overproductive	Suggestion: 1. Measure plankton productivety using standing crop, oxygen, pH, or carbon-14 method (or combination)
5. Fish Behavior	
Many fish observed to be "topping" (gulping air and/or splashing on surface)	Sug: 1. Check DO, IDOD, and BOD. 2. Check for toxic or oxygen demanding chemicals. 3. Determine organic content of water and bottom debris and/or sediments. 4. Check temp.

Table 1 - C - 2 Bacteriological Observations

In Case of:	Look for or Expect:
High Coliform Count	A. Raw or unchlorinated sewage discharge. B. Pasture or feed lot drainage. C. Storm sewer drainage immediately after a rain storm.
Low Coliform Count	A. Clean water. B. Heavily chlorinated sewage effluent. C. Toxic discharge as from pharmaceutical company manufacturing antibiotics, or toxic chemicals. D. Other source of toxicity such as acid mine drainage.

Table 1 - C - 3 Chemical Observations

In Case of:	Look for or Expect:
High DO's (12-30 mg/l) during daylight hours (supersaturation)	A. High biological productivity, especially producers (plants). B. Relatively quiet waters. C. Chemical interference in oxygen determination. Suggestion: 1 Check DO between

In Case of:	Look for or Expect:
High DO's Con"t	2:00 and 3:00 AM 2. Check DO at 1 or 2 hour intervals around the clock and graph results. 3. Search for source of excessive fertility. 4. Examine bottom muds for black anaerobic foul smelling (H_2S) deposits overgrown by plants. 5. Compare DO above and below a dam or rapids area. De-aeration may be detected.
Low DO's (0-4 mg/l) (in daytime)	A. High organic content, both dissolved and suspended solids. B. High total bacteria (MPN) and fungus count. C. If clear water, look for anaerobic spring (groundwater). D. Chemical interference in oxygen determination. E. Note water temperature. Suggestion: 1. Check for coliform bacteria. 2. See "Physical, Low Velocity" Suggestion #1.
Toxic chemicals in general.	Reduced biological productivity, may be selective or complete.

In Case of:	Look for or Expect:
Toxic or smothering chemicals which sink to bottom.	No living organisms on or in bottom materials, but overlying water may have rich plankton and/or nekton population.
Floating oil slick	A. Low DO near surface. B. Oil coated wharf pilings, floats, and shore. C. Dead or dying oil soaked birds and aquatic mammals. D. No living organisms on oil covered surfaces. If in an estuary or open, ocean front shore, this includes the entire intertidal zone.
High pH (8-11) High alkalinity (200 or more) High hardness (300 or more)	A. High turbidity. B. High biological productivity. C. If low biological production, look for toxicity, or biologically intolerable combination of chemicals. D. May be of natural origin.
Low pH (2-5)	A. Acid mine drainage or industrial discharge. B. Low biological productivity. C. Low turbidity.

In Case of:	Look for or Expect:
Specific chemical effects.	See Table 1-D of Appendix 1

Table 1 - C - 4 Physical Observations

In Case of:	Look for or Expect:
High velocity and turbulence	A. DO approximately at saturation for temperature. B. Hard bottom, little sediment. C. Biological organisms adapted to swift water. D. Particulate materials kept in suspension. E. Bank and bottom scouring (erosion)
Low velocity	A. DO may be above or below saturation. B. Coarse particulates may settle to bottom. C. Bottom may be soft. D. Organisms, if present, may be burrowers, or crawl freely on surface. Suggestions: 1. If turbidity is high, see High Velocity, item D., 2, Check for kinds and amounts of plankton.

In Case of:	Look for or Expect:
High volume of flow: normal, non-flood conditions (over 1000 cfs).	A Note: This is probably a "big" river". B. These are difficult and expensive to study, even for professional groups. Suggestions: 1. Examine the water for plankton. 2. Place artificial substrates for both periphyton and macroinvertebrates. 3. Carry out chemical and physical analyses of water.
Flood conditions (any stream)	A. High Coliform count in first few hours, diminishing as time goes on. B."Dumping" of waste holding ponds by industry. C. "By-passing" of sewage treatment plants. C. See also "physical" High Velocity, item D and Low Velocity, item B.
Low volume of flow (Up to 1000 cfs)	A. Note: Smaller streams from 0 up to 2 or 300 cfs are generally most satisfactory for group studies, but much depends on local circumstances, resources, and objectives. B. Most of the analyses described can be carried

In Case of:	Look for or Expect:
Low vol. con't	out on such a stream.
Heated water discharge (no chemical pollution assumed although heated discharges often contain chlorine or other chemicals used to kill biological growths in the plant. In this case, see also, Toxic Chemical sec.)	A. Differences between the biota in or near the discharge canal or pipe, and that in or around the intake. B. Artificial substrates may be used. Suggestions: 1. Make the above comparison winter and summer, or even better, each season. 2. Chart the dispersal of the heated water on the receiving water at different times of the year, different wind directions, different tidal phases, etc.. If available use depth recording thermometer and include depth as well as surface temperature. Graft your results.
Lakes, reservoires, and estuaries.	A. Thermal (or other density caused) stratification. B. Changes in water level, either natural or man made. Suggestions. 1. Practically every suggestion offered elsewhere for

In Case of:	Look for or Expect:
	stream or river pollution studies can be applied to lakes, reservoires or estuaries, making due allowance for differences in the basic nature of the waters. 2. Stratification, seiches, density currents, tidal currents, and salinity are additional physical factors to be considered. 3. Biological procedures are virtually identical, but while DO is the same, most of the chemical methods cited apply to freshwater only.

Figure 1 - C - 1 Benthos Responses to Pollution

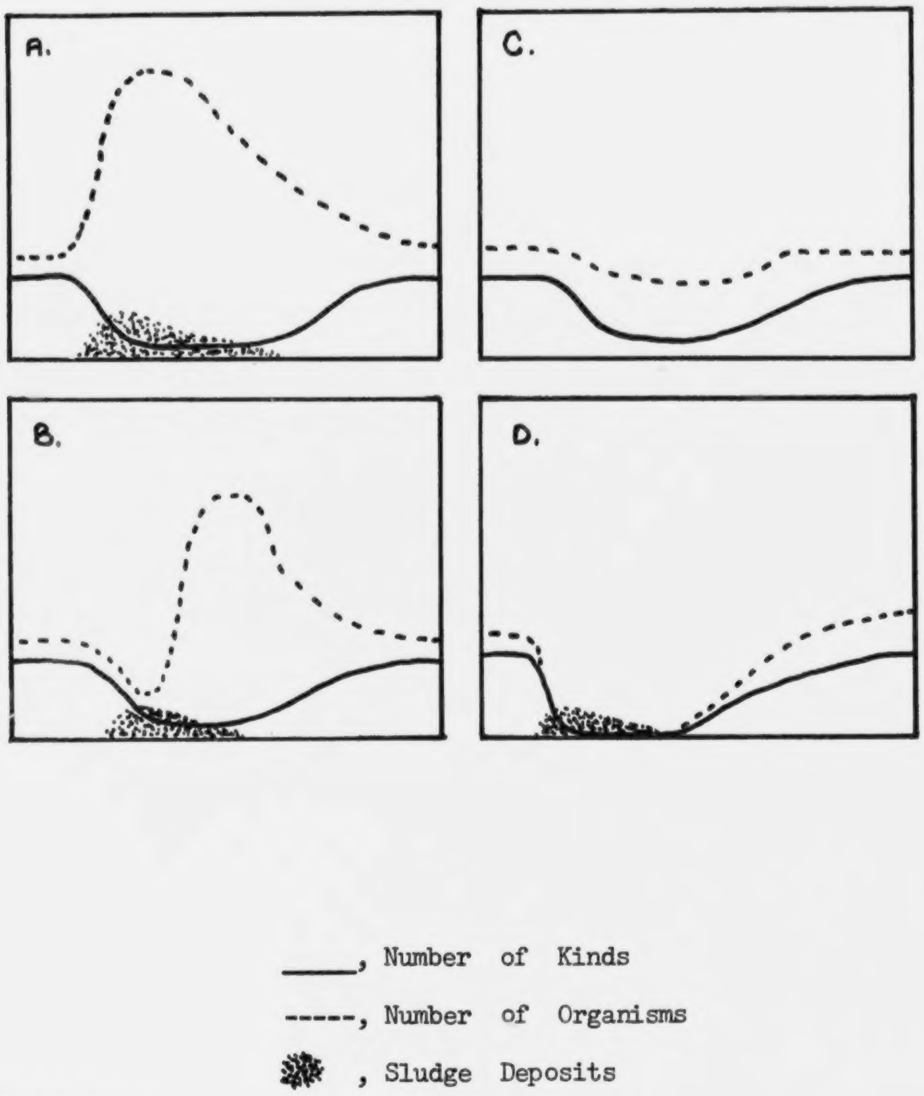

A.
C.
B.
D.
____, Number of Kinds
-----, Number of Organisms
▨ , Sludge Deposits

Figure 1 - C - 1

Four basic responses of bottom animals to pollution.

A. Organic wastes eliminate the sensitive bottom animals and provide food in the form of sludges for the surviving tolerant forms.

B. Large quantities of decomposing organic wastes eliminate sensitive bottom animals and the excessive quantities of by-products of organic decomposition inhibit the tolerant forms; in time, with natural stream purification, water quality improves so that the tolerant forms can flourish, utilizing the sludges as food.

C. Toxic materials eliminate the sensitive bottom animals; sludge is absent and food is restricted to that naturally occurring in the stream, which limits the number of tolerant surviving forms. Very toxic materials may eliminate all organisms below a waste source.

D. Organic sludges with toxic materials reduce the number of kinds by eliminating sensitive forms. Tolerant survivors do not utilize the organic sludges because the toxicity restricts their growth.

6. Bibliography

The following references are offered as extentions and additions to the material presented in this section.

Cairns, J. Jr., et.al., The Sequential Comparison Index-A Simplified Method for Non-Biologists to Estimate Relative Differences in Biological Diversity in Stream Pollution Studies, p. 1607-1613, Journal Water Pollution Control Federation, Washington, D.C. 20016, 1968

An excellent article. Recommended.

American Fisheries Society, A List of Common and Scientific Names of Fishes From the United States and Canada, Special Publication #2, Am. Fish. Soc., Suite 1040 Washington, D.C. 20005, 1960

This is a worthwhile reference for the "official" common name for the various species. It is not an identification key.

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A fair reference which is easily carried in the field.

Edmondson, W.T., Fresh-Water Biology . 2nd ed. John Wiley and Sons, Inc., New York

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Foerster, J.W., A Phyco-Periphyton Collector, Turtox News, 47-3, p. 82-84, 1969

Describes a simple, easy-to-make periphyton collector The periphyton is collected on glass microscope slides.

Gardiner, A.C., Measurement of Phytoplankton Population by the Pigment Extraction Method, Journal of the Marine Biological Association, 25 (4): 739-744, 1943

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Highly recommended. The author uses this hardy hirudinean to explain the sequential biological distention of parameters.

Pennak, R.W., Fresh-Water Invertebrates of the United States, Ronald Press, New York.

A good general reference. Very technical. Cost is around $15.

Pollison, D.P., and W.M. Craighead, Lehigh River Biological Investigation, Delaware River Basin Commision p. 24-25, Trenton, New Jersey. 1968

A comprehensive report on a river study. A biomonitoring technique is described; the report calls it a bioassay.

Needham, J.G., and P.R. Needham, A Guide to the Study of Fresh-Water Biology, Holden-Day, Inc., San Fracisco. (paper)

A good reference book. Excellent drawings of organisms.

Special Publication Number 1, Sources of Limnological and Oceanographic Apparatus and Supplies, American Society of Limnology and Oceanography.

Many specialized items of biological collecting equipment are not available from the usual supply houses. This publication lists the suppliers. It is available from the secretary of the society.

Standard Methods for the Examination of Water and Wastewater, 13th ed., American Public Health Association, Inc., New York 10019

Discusses biological collection techniques, bioassays, and chemical analysis. Good drawings of organisms. Every school should have at least one copy.

Wilhm, J.L., Patterns of Numerical Abundance of Animal Populations, p 147-150, The American Biology Teacher, March 1969.

A diversity index is presented as well as other means of statistically analyzing biological data.

Wilhm, J.L., and T.C. Dorris, Biological Parameters for Water Quality Criteria, p. 477-481, Bio Science 18-6 June 1968

A comprehensive discussion of diversity index.

D. Engineering and Physics

A number of useful tools which relate to the previously discussed chemical, bacteriological, and biological parameters are used in water studies. In the Engineering and Physics section, mapping, flow measurements, and computer use are discussed as they apply to water pollution and water surveys.

Map reading can facilitate water survey planning and provide a better understanding of the body of water being studied. Flow measurement provides valuable data in interpreting variations in results from chemical, bacteriological, and biological samplings. And the computer is a valuable tool in compiling sampling data. A working knowledge in these three areas will aid in water studies and the interpretation of collected data.

1. Mapping

In water surveys maps provide an invaluable tool for the recording of sampling sites and for providing information on water sources and possible points of pollution. For example, in the initial planning of a river study a topographic map is useful for indicating incoming streams and whether those streams pass through populated areas. Local sewage pipe-line maps, obtained through the city engineer or department of public works, will pinpoint sources. Thus, before any field work is done, a fairly good idea of possible sources of pollution may be obtained through the use of maps.

When a small area is being studied, such as a pond, a map can be easily drawn using the plane-table survey method. This method may be used in grade levels 6-12.

a. Equipment

(1) Tape measure

(2) Wooden stakes

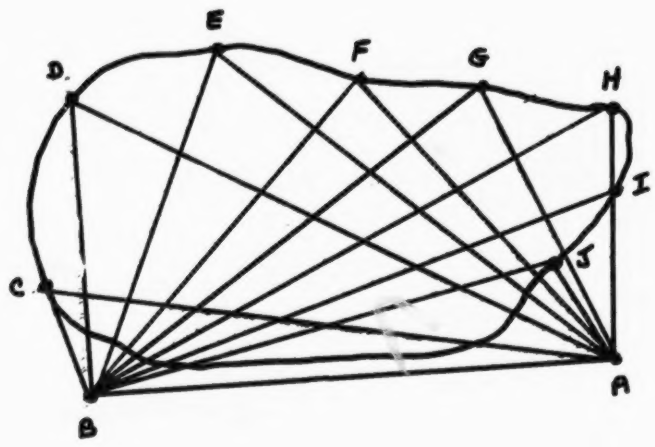
(3) A light weight table or head board with some type of support (i.e. legs).

(4) Paper, pencil, ruler

(5) Plumb line or carpenter's level

b. Procedure

Before the following procedure is started, the mappers should reconnoiter the pond to become familiar with it.



(1) Determine a base line from the ends (A,B) of which almost all points on the shore line (C-J) are visible. Place stakes at point A and B.

(2) Place stakes along the shoreline (C-J) so that they are visible from points A and B.

(3) Place the table or head board at point A. Using the plumb line or carpenter's level, make sure the table is horizontal.

(4) Tape a piece of paper to the table. At eye level to the table, line up stake B with a ruler and draw a line toward the sighting. This line is called the base line.

(5) From point A line up the other stakes (C-J) with a ruler and draw a ling along the line of sight.

(6) Measure the distance between point **A** and point B with a tape measure.

(7) On the base line sketched in step (4) place point B according to the scale desired. For instance, if the distance between point A and B is 100 feet, point B could be placed 10 inches from point A on the sketched base line. This would give a scale of "1 inch equals 10 feet."

(8) Move the table to point B and again make sure the table is horizontal.

(9) Align the map so that point A may be seen by placing a ruler along the base line and sighting along the top of the ruler.

(10) As soon as the base line is aligned, sight points C-J and draw the lines toward the sightings.

(11) The lines drawn from point B should intersect those lines drawn from point A. Darken those points and erase the construction lines.

(12) Connect all the points with a continuous line. The map is now to scale as determined in step (7).

(13) Fill the map in with whatever information is pertinent (e.g. north-bearing direction, stream inlets, houses, etc.)

c. References and Resources

Limnological Methods, Welch, P.S., McGraw-Hill.

Field Ecology, Phillips, E.A., D.C. Heath Co., Boston, 1964.

Topographic maps of any area in the United States may be obtained through the Geological Survey, Department of the Interior, Distribution Section, Washington, 25, D.C. State index circulars and a folder describing topographic maps may be obtained free from the above address.

2. **Flow.**

Flow measurements, the velocity and volume of water in a stream, are among the more important data collected in a water survey.

The velocity of water movement will determine the types of organisms living in a particular segment of a stream. Likewise, the velocity will affect the transport of nutrients and organic food past those organisms attached to stationary surfaces; the transport of plankton and benthos as drift, which in turn serve as food for higher organisms; the transport of silts and sediments; and the addition of dissolved oxygen through surface aeration.

The volume of water in a stream determines to what extent toxic substances and bacteria are diluted and, therefore, the immediate effects of an effluent on a streams's condition. Flow measurements should be determined whenever chemical, bacteriological, or biological samplings are taken. Variations in chemical, bacteriological, or biological results can often be attributed to flow variations.

Elaborate apparatus is usually used in flow gauging studies, such as current meters and weirs. The floatation method of estimating flow, however, can be achieved with simple equipment by students in the 7th - 12th grades.

a. Velocity:

(1) Equipment

(a) A floating object (float). This float is to be carried along by the water and should be as immune as possible to air flow and should be as visible as possible. In deep water, an Orange satisfies the needs and for smaller streams, smaller floats such as corks or rubber balls have been found very useful.

(b) Measuring tape or calibrated rope in feet.

(c) Stopwatch or watch with second hand.

(d) Boots.

(2) Procedure

(a) It is most difficult to measure flow in slowly moving waters that are over four feet deep. This would mean that a stream with rapids would be best to use for the float.

(b) Locate two points in center of stream, any measureable distance apart.

(c) Measure and record the distance between the two points, making sure that the area is free of any obstructions. (rocks, garbage, etc.)

(d) The moment you place the float at the upstream point, start timing.

(e) Mark the time the instance the float passes the downstream point.

(f) Using the formula, $V(\text{Velocity}) = \frac{D(\text{distance})}{T\ (\text{time})}$, Compute the value.

Note

Average velocity should be calculated to determine the true velocity of the stream. It can be concluded that the water of a stream or river will flow fastest on the surface at the center, and that the average velocity of a stream will therefore be less than the surface velocity.

(g) To obtain the average velocity, multiply the surface velocity by the constant bottom type factor; 0.9 for smooth bottomed streams or rivers (sand, clay etc.) and 0.8 for rough bottomed streams or rivers (rocks, debris, etc.)

b. Volume:

(1) Equipment

(a) A meter or yard stick or a measuring tape for measuring the depth and width.

(b) A slide rule, if desired, for calculating the results.

(2) Procedure

(a) Find the average width in feet of the stream between the same two points used in velocity measurements by finding the width at regular intervals between the points and taking the average of the widths.

(b) Determine the average depth in feet of the streams between the points, a certain number of depths from one side of the stream to the other. Take the average of these depths at each intervals, and then take the average of the average depth for the entire distance between the two points.

(c) Compute the average cross section of the stream in square feet between the two points by multiplying the average width by the average depth.

(d) Compute the volume of flow in second-feet (sec. /ft.) by multiplying the average cross-section by the average velocity in feet per second obtained from the velocity calculations. The breakdown of units of measurement in the calculations is as follows:

$$(\text{feet})^2 \times \frac{\text{feet}}{\text{sec.}} = \frac{(\text{feet})^2}{\text{sec.}} \text{ or ft. }^3/\text{sec.}$$

When flow measurements are being taken from a stream or river in which wading would be dangerous or impossible, a boat may be used or measurements may be taken from a bridge.

References:

The Practice of Water Pollution Biology, U.S. Department of the Interior, 1969, for sale through the Supt. of Documents.

This paperback contains only half a page on flow but is a food text for acquatic biology.

Manual on Water, American Society for testing and Materials, 1916 Race St., Philadelphia, Pa.

This text has a chapter on flow measurement but deals with the equipment of interest to industries.

Grover, N.C., and Harrington, A.R., Stream Flow, Dover Publications, New York.

A good paperback dealing, among other things, with methods and instruments for measuring stream flow.

Appendix, [illegible] Draft

Computer Applications

The volumes of data generated from the activities in this text can be handled most efficiently by a digital computer. The computer's speed and accuracy is readily adapted to the field of pollution studies as a tool for the ecologist. Though not everyone is an accomplished programmer, programs can be generated in the timeshare 'BASIC' language that can be run by most everyone.

The following programs are written with the non-programmer in mind. By using the Dartmough College computer, through a remote teletype terminal, anyone who can type, can access the system, call up the appropriate program (title known from an annotated catalog), and run that program to obtain the necessary results from his experiment. The conversational nature of the Dartmough "BASIC"[1] language permits the programmer to write a "prompting" type of program, so that the user gets the feeling that he is having a "conversation."

These programs are not restricted to the Dartmouth system alone. With minor changes, they can be accepted by most timeshare systems, or can be rewritten in Fortran for non-timeshare systems (though they then lose their conversational nature). Local conditions will dictate how the computer can be adapted as a tool for the ecologist.

---

[1] BASIC, Preliminary 5th Edition, Kemeny and Kurtz, Dartmouth Press, 1969.

STREAM

STREAM calculates the crossection, velocity and volume of flow of a stream. Input the site information (site number and location), the distance in feet from one depth reading to the next, the depth at each reading in feet and inches, the number of velocity trials, the distance in feet and inches of each trial, and the travel time in seconds for each trial. The method of calculating crossection uses a series of triangular and rectangular areas, where field accuracy dictates volumetric accuracy. The output is a summary of crossectional area in $ft.^2$, stream velocity in ft./sec. and volume of flow in $ft.^3$/ sec. A question is then asked as to whether you want a plot or not. A "yes" will produce a plot of the crossection of the stream at the site of study. A "RUN" and "LIST" follows.

```
RUN

STREAM    09 AUG 70  20:39



THIS PROGRAM CALCULATES CROSSECTION,VELOCITY,FLOW VOLUME
AND PLOTS THE CROSSECTIONAL PROFILE.

DIRECTIONS: ANSWER COMPUTER QUESTIONS.

                 STREAM CROSSECTION CALCULATION.

SITE NO.? 3
LOCATION? WINNESQUAM RIVER
WIDTH OF STREAM (F,I)? 50,0
HOW MANY DEPTH READINGS WERE TAKEN? 13
DISTANCE FROM SHORE TO FIRST MEASUREMENT(FT.) AND DEPTH (F,I)? 5,2,0
DISTANCE(F),DEPTH(F,I)? 3,3,0
DISTANCE(F),DEPTH(F,I)? 2,4,0
DISTANCE(F),DEPTH(F,I)? 2,4,0
DISTANCE(F),DEPTH(F,I)? 3,5,0
DISTANCE(F),DEPTH(F,I)? 2,6,0
DISTANCE(F),DEPTH(F,I)? 3,7,0
DISTANCE(F),DEPTH(F,I)? 4,5,0
DISTANCE(F),DEPTH(F,I)? 3,4,0
DISTANCE(F),DEPTH(F,I)? 3,3,0
DISTANCE(F),DEPTH(F,I)? 5,2,0
DISTANCE(F),DEPTH(F,I)? 5,1,0
DISTANCE(F),DEPTH(F,I)? 5,1,0
DISTANCE FROM LAST DEPTH TO SHORE? 5

                 AVERAGE VELOCITY CALCULATION.

HOW MANY TRIALS WERE CONDUCTED? 2
DISTANCE BETWEEN POINTS(FT.,IN.)? 48,0
TIME OF FLOAT(SEC.)? 16.2
DISTANCE BETWEEN POINTS(FT.,IN.)? 50,0
TIME OF FLOAT(SEC.)? 17.5
WAS THE STREAM 1)SMOOTH OR 2) ROUGH BOTTOMED? 1

DATA FOR:WINNESQUAM RIVER

THE AVERAGE VELOCITY OF STREAM AT SITE 3  IS  2.62 FT./SEC.

THE CROSSECTION IS  147  SQ.FT.

THE VOLUME OF FLOW IS  385.1  FT.↑3/SEC.

 DO YOU WISH A PLOT? YES
```

```
          CROSSECTION AT SITE  3  ON WINNESQUAM RIVER
MEASUREMENT                  WATER LEVEL
BANK                               *
                                   .
                                   .
                                   .
                                   .
 5   ( 2 )                       * .
                                   .
                                   .
 8   ( 3 )                      *  .
                                   .
 10  ( 4 )                     *   .
                                   .
 12  ( 4 )                     *   .
                                   .
                                   .
 15  ( 5 )                    *    .
                                   .
 17  ( 6 )                   *     .
                                   .
                                   .
 20  ( 7 )                  *      .
                                   .
                                   .
                                   .
 24  ( 5 )                    *    .
                                   .
                                   .
 27  ( 4 )                     *   .
                                   .
                                   .
 30  ( 3 )                      *  .
                                   .
                                   .
                                   .
                                   .
 35  ( 2 )                       * .
                                   .
                                   .
                                   .
                                   .
 40  ( 1 )                        *.
                                   .
                                   .
                                   .
                                   .
 45  ( 1 )                        *.
                                   .
                                   .
                                   .
                                   .
BANK ( 50 )                        *
DO YOU HAVE ANOTHER SITE TO CALCULATE? NO
```

STREAM

```
100'
110' CALCULATES CROSSECTION,VELOCITY,FLOW VOLUME AND PLOTS SITE PROFILE
120'
130 PRINT
140 PRINT
150 PRINT "THIS PROGRAM CALCULATES CROSSECTION,VELOCITY,FLOW VOLUME "
155 PRINT "AND PLOTS THE CROSSECTIONAL PROFILE."
170 PRINT
180 PRINT "DIRECTIONS: ANSWER COMPUTER QUESTIONS."
190 PRINT
200 PRINT TAB(15);"STREAM CROSSECTION CALCULATION."
210 PRINT
220 PRINT "SITE NO.";
230 INPUT S1
240 PRINT "LOCATION";
250 INPUT L$
260 PRINT "WIDTH OF STREAM (F,I)";
270 INPUT W,W5
280 LET W=W+W5/12
290 PRINT "HOW MANY DEPTH READINGS WERE TAKEN";
300 INPUT R
310 PRINT"DISTANCE FROM SHORE TO FIRST MEASUREMENT(FT.) AND";
320 PRINT " DEPTH (F,I)";
330 INPUT D(1),H(1),I(1)
340 LET H(1)=H(1)+I(1)/12
350 LET W1=D(1)
360 FOR J=2 TO R
370 PRINT "DISTANCE(F),DEPTH(F,I)";
380 DIM D(20),H(20), I(20)
390 INPUT D(J),H(J),I(J)
400 LET H(J)=H(J)+I(J)/12
410 LET W1=W1+D(J)
420 NEXT J
430 PRINT "DISTANCE FROM LAST DEPTH TO SHORE";
440 INPUT D(R+1)
450 LET W1=W1+D(R+1)
460 IF W1=W THEN 540
470 PRINT
480 PRINT "ERROR IN WIDTH MEASUREMENT."
490 PRINT
500 PRINT "DO YOU WISH TO CONTINUE";
510 INPUT R$
520 IF R$="YES" THEN 540
530 STOP
540 LET T=.5*D(1)*H(1)
550 LET W=W1
560 FOR I=1 TO R-1
570 IF H(I+1)>H(I) THEN 610
580 LET T=T+.5*(H(I)-H(I+1))*D(I+1)+D(I+1)*H(I+1)
590 NEXT I
```

STREAM (CONTINUED)

```
600 GO TO 630
610 LET T=T+.5*(H(I+1)-H(I))*D(I+1)+H(I)*D(I+1)
620 GO TO 590
630 LET T=T+.5*D(R+1)*H(R)
640'VELOCITY
650 PRINT
660 PRINT TAB(15);"AVERAGE VELOCITY CALCULATION."
670 PRINT
680 PRINT "HOW MANY TRIALS WERE CONDUCTED";
690 INPUT K
700 LET V=0
710 FOR J=1 TO K
720 PRINT "DISTANCE BETWEEN POINTS(FT.,IN.)";
730 INPUT F(J),I(J)
740 LET F(J)=F(J)+I(J)/12
750 PRINT "TIME OF FLOAT(SEC.)";
760 INPUT S(J)
770 LET V=F(J)/S(J)+V
780 NEXT J
790 LET V=V/K
800 PRINT "WAS THE STREAM 1)SMOOTH OR 2) ROUGH BOTTOMED";
810 INPUT A
820 IF A=2 THEN 850
830 LET V=V*.9
840 GO TO 860
850 LET V=V*.8
860 PRINT
870 PRINT "DATA FOR:";L$
880 PRINT
885 LET V=INT(100*V+.5)/100
890 PRINT "THE AVERAGE VELOCITY OF STREAM AT SITE";S1;" IS ";
900 PRINT V;"FT./SEC."
910 PRINT
915 LET T=INT(100*T+.5)/100
920 PRINT "THE CROSSECTION IS ";T;" SQ.FT."
930 PRINT
935 LET F=INT(10*T*V+.5)/10
940 PRINT "THE VOLUME OF FLOW IS ";F;" FT.↑3/SEC."
950 PRINT
960 PRINT " DO YOU WISH A PLOT";
970 INPUT R$
980 IF R$="YES" THEN 1000
990 STOP
1000 GOSUB 1060
1010 PRINT
1020 PRINT"DO YOU HAVE ANOTHER SITE TO CALCULATE";
1030 INPUT R$
1040 IF R$="YES" THEN 190
1050 STOP
1060'PLOT
```

STREAM (CONTINUED)

```
1070 PRINT
1080 PRINT
1090 PRINT
1100 PRINT TAB(10);"CROSSECTION AT SITE ";S1;" ON ";L$
1110 PRINT
1120 PRINT "MEASUREMENT";TAB(29);"WATER LEVEL"
1130 PRINT
1140 PRINT "BANK";TAB(34);"*"
1150 LET J=1
1160 LET D9=D(J)
1170 FOR X=1 TO W-1
1180 IF X=D9 THEN 1210
1190 PRINT TAB(34);"."
1200 GO TO 1250
1210 IF H(J)<1 THEN 1270
1220 PRINT X;TAB(5);"(";H(J);")";TAB(34-INT(H(J)+.5));"*";TAB(34);"."
1230 LET J=J+1
1240 LET D9=D9+D(J)
1250 NEXT X
1260 GO TO 1290
1270 PRINT X;TAB(33);"*."
1280 GO TO 1230
1290 PRINT "BANK (";W;")";TAB(34);"*"
1300 RETURN
1310 END
```

DIV

DIV calculates the diversity index of a sample in a biotic community using the information and formulas presented in the article "Biological Parameters for Water Quality Criteria" by Jerry L. Wilhm and Troy C. Dorris presented in BIOSCIENCE Vol. 18, No. 6. The diversity index is an indication of pollution levels, for "values less than 1 have been obtained in areas of heavy pollution, values from 1 to 3 in areas of moderate pollution, and values exceeding 3 in clean water areas."[1] Refer to Activity E, Chapter 3.

This program is not conversational in nature so data must be inserted as DATA statements from line 720 on. These data statements must be of the following form: 146, 5, 131, 7, 4, 1, 3, 1, 1.86, etc., where 146 is the total number of individuals, 5 the number of individual types, 131 through 3 the numbers per individual population, 1 the site number, and 1.86 the biomass of that sample.

The output is a table listing the Individual diversity, diversity index, theoretical maximum and minimum diversity, and a redundancy factor. Redundancy expresses the dominance of a type, while diversity shows the compositional richness of a mixed-population aggregation of organisms.

A "RUN" and "LIST" follows.

---

[1] "Biological Parameters for Water Quality Criteria;" Wilhm and Dorris, BIOSCIENCE, Vol. 18, No. 6.

```
DIV        09 AUG 70  19:50

           INDIVIDUAL              MAXIMUM      MINIMUM
LOCATION   DIVERSITY   DIVERSITY   DIVERSITY    DIVERSITY    BIOMASS     R


    1       3.94323    0.657052    2.26021      0.196572     1.86   0.776861

    2       4.15551    1.34916     2.27043      0.165477     1.05   0.437667

    3       4.3029     0.777571    2.44827      0.184772     1.5  0.738105

    4       3.74413    0.49188     1.87177      0.173511     0.2  0.812532

    5       4.96296    1.01232     2.51868      0.107735     0  0.624798

    6       5.38642    5.36488 E-2  1.97682    4.63947 E-2  6.1  0.996242

    9       4.2596     1.59888     2.94719      0.30109      2.3  0.509546

   10       3.07844    1.27176     2.25769      0.465142     0.15  0.550017

   11       3.93598    0.583135    2.19182      0.198744     0.64  0.807137

   12       3.22023    1.01045     2.38556      0.425624     0.67  0.70161

   13       4.79031    0.730937    1.94339      7.50793 E-2  0.91  0.64

   14       2.79423    1.11113     1.82516      0.347148     2.36  0.483105

   15       4.92       0.711892    2.50029      0.112172     5.48  0.748873

   16       3.15433    0.820883    1.86566      0.267617     0.85  0.653786

   17       5.21978    0.259188    2.73366      0.105908     5.4  0.941669

   18       2.05037    1.80127     1.8543       0.748345     1.8  0.04795

   19       5.24932    0.20262     2.55626      8.62842 E-2  6.01  0.9529

   20       3.46477    1.45072     2.3364       0.346989     1.5  0.445195

   21       4.53496    0.830485    2.49195      0.152622     1.8  0.710232

   22       3.31442    1.62428     2.46072      0.466243     1.5  0.419378



R IS A REDUNANCY EXPRESSION WHICH IS THE
DOMINANCE OF ONE OR MORE SPECIES AND IS THE
INVERSE PROPORTION TO THE WEALTH OF THE SPECIES.
```

DIV

```
100 REM    SOURCE:BIOLOGICAL PARAMETERS FOR WATER QUALITY CRITERIA
110 REM    BY WILHM AND DORRIS   FROM BIOSCIENCE VOL.18 NO.6
120 REM
130 REM    PREPARED BY WPP - TILTON   SUMMER '70
140 REM
150 PRINT TAB(10);"INDIVIDUAL";TAB(32);"MAXIMUM";TAB(43);"MINIMUM"
160 PRINT "LOCATION";TAB(10);"DIVERSITY";TAB(21);"DIVERSITY";TAB(32);
170 PRINT "DIVERSITY";TAB(43);"DIVERSITY";TAB(54);"BIOMASS    R"
180 PRINT
190 PRINT
200 PRINT
210 GOSUB 310
220 GOSUB 460
230 GOSUB 530
240 GOSUB 620
250 READ O,R
260 IF O<10 THEN 700
270 PRINT TAB(2);O;
280 PRINT TAB(10);Q;TAB(21);E;TAB(32);M(1);TAB(43);
290 PRINT M(2);TAB(54);R;(M(1) -E)/(M(1)-M(2))
300 GOTO 200
310 DIM N(72),A(50)
320 READ Z
330 IF Z=0 THEN 840
340 LET N=LOG(Z)
350 FOR T=Z-1 TO 1 STEP -1
360 LET N=LOG(Z-T)+N
370 NEXT T
380 READ S
390 LET B=0
400 FOR C=1 TO S
410 READ A (C)
420 LET B=LOG(A(C))+B
430 NEXT C
440 LET Q=(1/Z)*(N-B)
450 RETURN
460 DIM E(72)
470 LET D=0
480 FOR I=1 TO S
490 LET D=(A(I)/Z)*LOG(A(I)/Z)/LOG(2)+D
500 NEXT I
510 LET E=-D
520 RETURN
530 LET F=N/LOG(2)
540 LET G=INT(Z/S+.5)
550 LET H=LOG(G)
560 FOR C=G-1 TO 1 STEP -1
570 LET H=LOG (C)+H
580 NEXT C
590 LET G=H/LOG(2)
```

DIV (CONTINUED)

```
600 LET M(1)=(F-S*G)/Z
610 RETURN
620 LET J=Z-(S-1)
630 LET K=LOG(J)
640 FOR C=J-1 TO 1 STEP -1
650 LET K=LOG(C)+K
660 NEXT C
670 LET K=K/LOG(2)
680 LET M(2)=(F-K)/Z
690 RETURN
700 PRINT TAB(3);O;
710 GO TO 280
720 DATA 146,5,131,7,4,1,3,1,1.86,181,5,99,68,1,1,12,2,1.05,208
730 DATA 6,180,1,18,3,1,5,3,1.5,119,4,110,4,1,4,4,.2,401,6,326
740 DATA 17,9,1,6,42,5,0,596,4,593,1,1,1,6,6.1,203,9,118,2,61
750 DATA 11,2,1,1,6,1,9,2.3,64,6,48,2,9,2,2,1,10,.15,144,5,131
760 DATA 6,5,1,1,11,.64,72,6,59,7,1,1
770 DATA 3,1,12,.67,335,4,288,15,31,1,13,.91,48,4,35,1,2,10
780 DATA 14,2.36,382,6,336,5,30,1,8,2,15,5.48,68,4,58,2,3,5
790 DATA 16,0.85,509,7,494,3,2,1,2,6,1,17,5.40,24,5,8,1,3
800 DATA 1,11,18,1.8
810 DATA 523,6,511,1,6,1,2,2,19,6.01,94,6,62,3,21,1,2,5,20,1.5
820 DATA 263,6,228,9,13,9,3,1,21,1.8,81,7,3,2,30,41,1,2,1,22,1.5
830 DATA 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
840 PRINT
850 PRINT
860 PRINT
870 PRINT
880 PRINT
890 PRINT
900 PRINT "R IS A REDUNANCY EXPRESSION WHICH IS THE"
910 PRINT "DOMINANCE OF ONE OR MORE SPECIES AND IS THE"
920 PRINT "INVERSE PROPORTION TO THE WEALTH OF THE SPECIES."
930 END
```

DIVERS

DIVERS is similar to DIV, except it incorporates Stirling's formula, $H = -E\ (Ni/N)\ \log_2\ (Ni/N)$[1] to indicate population diversity where N indicates total population count and Ni indicates count per individual type. The run time of this program is far less than DIV and the printout also gives a comment as to pollution level as noted under the comment for DIV.

This program is also non-conversational in nature and you must replace the data using DATA statements after line 370. The form is as follows: 1, 146, 5, 131, 7, 4, 1, 3, etc. Where 1 is the site number, 146 the total population, 5 the number of individual types, and 131-3 the number of each individual type.

A "RUN" and "LIST" follows.

---

[1] "Biological Parameters for Water Quality Criteria"; Wilhm and Dorris, BIOSCIENCE, vol. 18, No. 6.

```
RUN

DIVERS     09 AUG 70  19:57

LOCATION  DIVERSITY          COMMENT


   1        0.657052       HEAVY POLLUTION.
   2        1.34916        MODERATE POLLUTION.
   3        0.777571       HEAVY POLLUTION.
   4        0.49188        HEAVY POLLUTION.
   5        1.01232        MODERATE POLLUTION.
   6        5.36488 E-2    HEAVY POLLUTION.
   9        1.59888        MODERATE POLLUTION.
   10       1.27176        MODERATE POLLUTION.
   11       0.583135       HEAVY POLLUTION.
   12       1.01045        MODERATE POLLUTION.
   13       0.730937       HEAVY POLLUTION.
   14       1.11113        MODERATE POLLUTION.
   15       0.709969       HEAVY POLLUTION.
   16       0.820883       HEAVY POLLUTION.
   17       0.259188       HEAVY POLLUTION.
   18       1.80127        MODERATE POLLUTION.
   19       0.20262        HEAVY POLLUTION.
   20       1.45072        MODERATE POLLUTION.
   21       0.830485       HEAVY POLLUTION.
   22       1.62666        MODERATE POLLUTION.

TIME: 0.168 SEC.
READY
```

DIVERS

```
100'
110'  SOURCE:BIOLOGICAL PARAMETERS FOR WATER QUALITY CRITERIA
120'  WILHM AND DORRIS - BIOSCIENCE VOL. 18 NO. 6
130'
140'  DIVERSITY USING STIRLING'S FORMULA
150'
160 PRINT
170 PRINT "LOCATION"; TAB(10); "DIVERSITY"; TAB(30); "COMMENT"
180 PRINT
190 PRINT
200 READ L,N,S
210 IF N=0.0 THEN 490
220 LET H=0.0
230 FOR I=1 TO S
240 READ N(I)
250 LET H=(N(I)/N) * (LOG(N(I)/N)/LOG(2)) + H
260 NEXT I
270 LET H=-H
280 PRINT TAB(2); L; TAB(10); H; TAB(26);
290 IF H<1 THEN 350
300 IF H<3 THEN 330
310 PRINT "CLEAN WATER."
320 GO TO 200
330 PRINT "MODERATE POLLUTION."
340 GO TO 200
350 PRINT  "HEAVY POLLUTION."
360 GO TO 200
370 DATA 1,146,5,131,7,4,1,3,2,181,5,99,68,1,1,12
380 DATA 3,208,6,180,1,18,3,1,5,4,119,4,110,4,1,4
390 DATA 5,401,6,326,17,9,1,6,42,6,596,4,593,1,1,1
400 DATA 9,203,9,118,2,61,11,2,1,1,6,1
410 DATA 10,64,6,48,2,9,2,1,2
420 DATA 11,144,5,131,5,6,1,1,12,72,6,59,7,1,1,3,1
430 DATA 13,335,4,288,15,31,1,14,48,4,35,1,2,10
440 DATA 15,381,6,336,5,30,1,8,2,16,68,4,58,2,3,5
450 DATA 17,509,7,494,3,2,1,2,6,1,18,24,5,8,1,3,1,11
460 DATA 19,523,6,511,1,6,1,2,2,20,94,6,62,3,21,1,2,5
470 DATA 21,263,6,228,9,13,9,3,1,22,80,7,3,2,30,41,1,2,1
480 DATA 0,0,0
490 END
```

DPLOT

DPLOT is a teletype plotting program for data. Some programming changes are necessary to alter the scale (at present, the program is set from 0 to 3). Since 60 is a reasonable teletype size (70 is maximum) a factor must be devised to multiply the result by in line 270 so as to equal 60 (i.e. for a high scale of 3, multiply by 20). It is necessary to change line 390 to indicate the new scale, and to divide the result (namely R(I)) by the appropriate multiple in lines 510 and 560.

Input location, name of test, date, remarks (if any), site number, and result at that site. The output will be a scaled graph on which the site numbers and results at each site will be printed.

A "RUN" and "LIST" follows.

```
OLD DPLOT
READY

RUN

DPLOT      09 AUG 70  19:58

LOCATION ? NESHEMINY
TEST RESULTS FOR ? DIVERSITY
DATE TAKEN ? 6-24-69
REMARKS? COMPLETE WATERSHED
NO. OF SITES TESTED ? 20
SITE NO. AND RESULTS? 1,0.6571
SITE NO. AND RESULTS? 2,1.3492
SITE NO. AND RESULTS? 3,0.7776
SITE NO. AND RESULTS? 4,0.4919
SITE NO. AND RESULTS? 5,1.0123
SITE NO. AND RESULTS? 6,0.05365
SITE NO. AND RESULTS? 9,1.5988
SITE NO. AND RESULTS? 10,1.2718
SITE NO. AND RESULTS? 11,0.5831
SITE NO. AND RESULTS? 12,1.0105
SITE NO. AND RESULTS? 13,0.7309
SITE NO. AND RESULTS? 14,1.1111
SITE NO. AND RESULTS? 15,0.7099
SITE NO. AND RESULTS? 16,0.8209
SITE NO. AND RESULTS? 17,0.2592
SITE NO. AND RESULTS? 18,1.8013
SITE NO. AND RESULTS? 19,0.2026
SITE NO. AND RESULTS? 20,1.4507
SITE NO. AND RESULTS? 21,0.8305
SITE NO. AND RESULTS? 22,1.6266
```

```
TEST RESULTS FOR DIVERSITY TAKEN ON 6-24-69 ON NESHEMINY

REMARKS: COMPLETE WATERSHED

     SCALE FROM 0 TO 3.

     ....................+...................+....................
     .
 1   .            *( 0.6571 )
     .
 2   .                          *( 1.3492 )
     .
 3   .              *( 0.7776 )
     .
 4   .        *( 0.4919 )
     .
 5   .                   *( 1.0123 )
     .
 6   .*( 0.05365 )
     .
 9   .                               *( 1.5988 )
     .
 10  .                        *( 1.2718 )
     .
 11  .          *( 0.5831 )
     .
 12  .                   *( 1.0105 )
     .
 13  .             *( 0.7309 )
     .
 14  .                     *( 1.1111 )
     .
 15  .             *( 0.7099 )
     .
 16  .               *( 0.8209 )
     .
 17  .    *( 0.2592 )
     .
 18  .                                   *( 1.8013 )
     .
 19  .   *( 0.2026 )
     .
 20  .                            *( 1.4507 )
     .
 21  .               *( 0.8305 )
     .
 22  .                                *( 1.6266 )


TIME: 0.330 SEC.
READY
```

DPLOT

```
110' PLOT ROUTINE FOR DATA
120'
130 DIM S(30),R(30)
140 PRINT "LOCATION ";
150 INPUT L$
160 PRINT "TEST RESULTS FOR ";
170 INPUT T$
180 PRINT "DATE TAKEN ";
190 INPUT D$
200 PRINT "REMARKS";
210 INPUT R$
220 PRINT "NO. OF SITES TESTED ";
230 INPUT N
240 FOR I=1 TO N
250 PRINT "SITE NO. AND RESULTS";
260 INPUT S(I),R(I)
270 LET R(I)=R(I)*20
280 NEXT I
290 PRINT
300 PRINT
310 PRINT
320 PRINT
330 PRINT "TEST RESULTS FOR ";T$;" TAKEN ON ";D$;" ON ";L$
340 PRINT
350 PRINT "REMARKS: ";R$
360 PRINT
370 PRINT
380 PRINT TAB(5);
390 PRINT "SCALE FROM 0 TO 3."
400 PRINT
410 PRINT TAB(5);
420 FOR I=1 TO 61
430 IF I=21 THEN 580
440 IF I=41 THEN 580
450 PRINT ".";
460 NEXT I
470 PRINT
480 FOR I=1 TO N
490 PRINT TAB(5);"."
500 IF R(I)=0 THEN 560
510 PRINT S(I);TAB(5);".";TAB(R(I)+5);"*";"(";R(I)/20;")"
520 NEXT I
530 PRINT
540 PRINT
550 GO TO 600
560 PRINT S(I);TAB(5);"*";TAB(9);"(";R(I)/20;")"
570 GO TO 520
580 PRINT "+";
590 GO TO 460
600 END
```

ANALYZE

ANALYZE is programmed to help analyze a sample of water quickly and accurately. It uses as its parameters: ph, CØ$_2$, DØ, IDØD, BØD, CØLIFØRM, FECAL CØLIFØRM FECAL STREP, and PHØSPHATE.

Input location, site number, date, and the above parametric readings obtained from your tests. The output consists of general comments about each parametric result and, in some cases, suggests other tests that might be done to obtain a more complete analysis. A "RUN" and "LIST" follows.

```
RUN

ANALYZE   09 AUG 70  20:57


THIS PROGRAM IS DESIGNED TO HELP YOU ANALYZE YOUR SAMPLE.

LOCATION? WINNESQUAM RIVER
SITE #? 3
DATE? 3-24-70



DO YOU HAVE A PH READING? YES
READING? 6.2

DO YOU HAVE A CO2 READING? YES
READING? 18

DO YOU HAVE A DISSOLVED OXYGEN (D.O.) READING? YES
READING? 4
TEMP IN C? 13

DO YOU HAVE A READING OF IMMEDIATE DISSOLVED OXYGEN
DEMAND (I.D.O.D.)? YES
READING? 2

DO YOU HAVE A READING OF BIOLOGICAL OXYGEN DEMAND (B.O.D.)? YES
READING? 10

DO YOU HAVE A COLIFORM COUNT PER 100 ML.? YES
READING? 33766

DO YOU HAVE A READING OF FECAL COLIFORM PER 100 ML.? YES
READING? 250

DO YOU HAVE A FECAL STREP READING? YES
READING? 100

DO YOU HAVE A PHOSPHATES READING IN PPM.? YES
READING? 0.02
```

```
RESULTS FROM WINNESQUAM RIVER TAKEN ON 3-24-70 AT SITE  3 .


THE WATER IS NEUTRAL.

CO2 COULD BE A LIMITING FACTOR IF D.O. IS LOW AND
PH IS NOT 'NATURAL'.

D.O. IS LOW FOR CLASS 'A' WATERS.


AT  13  DEGREES C.,THE THEORETICAL D.O. SATURATION LEVEL IS
 10.6 .
THE PERCENT OF D.O. IN RELATION TO THE THEORETICAL
D.O. SATURATION IS 27 %.

THE O2 BALANCE IN THIS WATER IS POOR. CHECK I.D.O.D.,
B.O.D.,COLIFORM COUNT FOR POSSIBLE CLUES AS TO THE REASON.

NOTE: DISSO=D.O.-I.D.O.D.

DISSO OF  2  SHOWS OXYGEN DEMANDING MATERIAL IN THE WATER.

THE READING OF  10  FOR B.O.D. HAS NO DISTINCT
RELATIONSHIP TO D.O. BECAUSE OF A VOLUMETRIC DIFFERENCE.

TOTAL COLIFORMS ARE CONSIDERED 'RELIABLE' INDICATORS
AS TO THE POSSIBLE PRESENCE OF BACTERIAL PATHOGENS...
SINCE THE TOTAL COUNT IS  33766  PER 100ML. ,THIS BODY
OF WATER IS UNFIT FOR HUMAN CONTACT.

THE PRESENCE OF FECAL COLIFORMS IN WATER INDICATES
RECENT FECAL CONTAMINATION. SINCE THE FECAL COUNT WAS
REPORTED AS  250  PER 100 ML., THIS BODY OF WATER IS
UNFIT FOR PUBLIC WATER SUPPLY.

SINCE FECAL STREP EQUALS  100  THE CONTAMINATION
IS LIKELY HUMAN WASTE.

PHOSPHATES ARE PRESENT IN SUFFICIENT AMOUNTS, 0.02
 PPM, THAT COULD 'TRIGGER' AN ALGAL BLOOM,IF OTHER
CONDITIONS ARE RIGHT.


TIME: 0.998 SEC.
READY
```

ANALYZE

```
100'
110' WATER ANALYSIS PROGRAM
120'
130 PRINT
140 PRINT "THIS PROGRAM IS DESIGNED TO HELP YOU ANALYZE YOUR SAMPLE."
150 PRINT
160 PRINT "LOCATION";
170 INPUT L$
180 PRINT "SITE #";
190 INPUT S1
200 PRINT "DATE";
210 INPUT D$
220 MARGIN 65
230 PRINT
240 PRINT
250 PRINT
260 LET I=0
270 DIM A(20),B(60)
280 PRINT "DO YOU HAVE A PH READING";
290 GOSUB 1490
300 PRINT "DO YOU HAVE A CO2 READING";
310 GOSUB 1490
320 PRINT"DO YOU HAVE A DISSOLVED OXYGEN (D.O.) READING";
330 GOSUB 1490
340 PRINT "DO YOU HAVE A READING OF IMMEDIATE DISSOLVED OXYGEN"
350 PRINT "DEMAND (I.D.O.D.)";
360 GOSUB 1490
370 PRINT "DO YOU HAVE A READING OF BIOLOGICAL OXYGEN DEMAND (B.O.D.)
380 GOSUB 1490
390 PRINT "DO YOU HAVE A COLIFORM COUNT PER 100 ML.";
400 GOSUB 1490
410 PRINT "DO YOU HAVE A READING OF FECAL COLIFORM PER 100 ML.";
420 GOSUB 1490
430 PRINT "DO YOU HAVE A FECAL STREP READING";
440 GOSUB 1490
450 PRINT "DO YOU HAVE A PHOSPHATES READING IN PPM.";
460 GOSUB 1490
470 REM PH=A(1)  CO2=A(2)  O2=A(3)  IDOD=A(4)  BOD=A(5)  COLIFORM=A(6)
480 REM FECAL COLIFORM=A(7) FECAL STREP=A(8) PHOSPHATES=A(9)
490 PRINT
500 PRINT
510 PRINT "RESULTS FROM ";L$;" TAKEN ON ";D$;" AT SITE ";S1;"."
520 PRINT
530 PRINT
540 IF A(1)=-1 THEN 650
550 IF A(1)>8.6 THEN 640
560 IF A(1)>8.2 THEN 620
570 IF A(1)>5.999  THEN 600
580 PRINT "THE WATER IS ACIDIC."
590 GO TO 650
```

ANALYZE (CONTINUED)

```
600 PRINT "THE WATER IS NEUTRAL."
610 GO TO 650
620 PRINT "THE WATER IS SLIGHTLY ALKALINE."
630 GO TO 650
640 PRINT "THE WATER IS ALKALINE."
650 PRINT
660 IF A(2)=-1 THEN 770
670 IF A(2)>25 THEN 740
680 IF A(2)>15 THEN 710
690 PRINT "CO2 IS NOT A LIMITING FACTOR."
700 GO TO 770
710 PRINT "CO2 COULD BE A LIMITING FACTOR IF D.O. IS LOW AND ";
720 PRINT "PH IS NOT 'NATURAL'."
730 GO TO 770
740 PRINT "CO2 IS PROBABLY A LIMITING FACTOR.EXAMINE THE ";
750 PRINT "AREA WITH A DI-URNAL STUDY FOR POSSIBLE ALGAL ";
760 PRINT "BLOOM.  EXAMINE, ALSO, PH AND D.O. READINGS."
770 PRINT
780 IF A(3)=-1 THEN 1290
790 IF A(3)>8.2 THEN 830
800 IF A(3)>5 THEN 880
810 PRINT "D.O. IS LOW FOR CLASS 'A' WATERS."
820 GO TO 900
830 PRINT "THE D.O. IS HIGHER THAN IS 'NATURAL'.IF THE D.O. IS ";
840 PRINT "GREATER THAN 10, IT MAY INDICATE AN ALGAL BLOOM OR SOME ";
850 PRINT "'UNNATURAL' CONDITION.IT IS RECOMMENDED THAT A ";
860 PRINT "COMPLETE O2 ANALYSIS BE DONE AT THIS SITE."
870 GO TO 900
880 PRINT "D.O. IS PROBABLY NOT A LIMITING FACTOR AND WILL SUPPORT ";
890 PRINT "MOST FISH LIFE."
900 PRINT
910 PRINT
920 LET I=0
930 LET B(I)=14.6
940 FOR I=1 TO 50
950 READ B(I)
960 NEXT I
970 LET P=(A(3)/B(Q))*100
980 PRINT "AT ";T;" DEGREES C.,THE THEORETICAL D.O. SATURATION";
990 PRINT " LEVEL IS ";B(T);"."
1000 PRINT "THE PERCENT OF D.O. IN RELATION TO THE THEORETICAL ";
1010 LET P=INT(P+.5)
1020 PRINT "D.O. SATURATION IS";P;"%."
1030 DATA 14.2,13.8,13.5,13.1,12.8,12.5,12.2,11.9,11.6,11.3,11.1
1040 DATA 10.8,10.6,10.4,10.2,10.0,9.7,9.5,9.4,9.2,9.0,8.8,8.7,8.5
1050 DATA 8.4,8.2,8.1,7.9,7.8,7.6,7.5,7.4,7.3,7.2,7.1,7.0,6.9
1060 DATA 6.8,6.7,6.6,6.5,6.4,6.3,6.2,6.1,6.0,5.9,5.8,5.7,5.6
1070 IF P>=75 THEN 1170
1080 IF P>=50 THEN 1130
1090 PRINT
```

ANALYZE (CONTINUED)

```
1100 PRINT "THE O2 BALANCE IN THIS WATER IS POOR. CHECK I.D.O.D.,";
1110 PRINT "B.O.D.,COLIFORM COUNT FOR POSSIBLE CLUES AS TO THE REASON.
1120 GO TO 1290
1130 PRINT
1140 PRINT " THE O2 BALANCE IS FAIR. IT PROBABLY DOES NOT ACT AS A ";
1150 PRINT "LIMITING FACTOR,ESPECIALLY IF THE TEMP IS <15 CENT."
1160 GO TO 1290
1170 PRINT
1180 IF P>100 THEN 1250
1190 PRINT "THE O2 BALANCE IS GOOD,AND SHOULD INDICATE A HEALTHY ";
1200 PRINT "STREAM. NO ANAEROBIC CONDITIONS SHOULD BE PRESENT IF ";
1210 PRINT "A REPRESENTATIVE SAMPLE WAS TAKEN...CAUTION! CHECK ";
1220 PRINT "FLOW READINGS FOR THEY MAY MASK ACYUAL CONDITIONS."
1230 GO TO 1290
1240 PRINT
1250 PRINT "O2 FIGURES INDICATE A 'SUPER-SATURATED' CONDITION.";
1260 PRINT "RECHECK O2 READING. A SPECIES DIVERSITY IS RECOMMENDED ";
1270 PRINT "- ALONG WITH A COMPLETE ALGAL COUNT..."
1280 PRINT
1290 IF A(4)=-1 THEN 1440
1300 IF A(4)>A(3) THEN 1430
1310 IF A(4)<.5 THEN 1430
1320 LET D1=A(3)-A(4)
330 PRINT
.340 PRINT "NOTE: DISSO=D.O.-I.D.O.D."
1350 PRINT
1360 IF D1+3<0 THEN 1400
1370 PRINT "DISSO OF ";D1;" SHOWS OXYGEN DEMANDING MATERIAL IN THE ";
1380 PRINT "WATER."
1390 GO TO 1440
1400 PRINT "DISSO OF ";D1;" SHOWS OXYGEN DEMANDING MATERIALS IN THE ";
1410 PRINT "WATER ARE NOT A FACTOR."
1420 GO TO 1440
1430 GOSUB 1650
1440 IF A(5)=-1 THEN 1710
1450 PRINT
1460 PRINT "THE READING OF ";A(5);" FOR B.O.D. HAS NO DISTINCT ";
1470 PRINT "RELATIONSHIP TO D.O. BECAUSE OF A VOLUMETRIC DIFFERENCE."
1480 GO TO 1710
1490 INPUT R$
1500 LET I=I+1
1510 IF R$="NO" THEN 1620
1520 IF R$="YES" THEN 1580
1530 PRINT "INCORRECT FORMAT, PLEASE TYPE YES OR NO."
1540 PRINT "DO YOU HAVE A READING";
1550 INPUT R$
1560 GO TO 1510
1570 PRINT
1580 PRINT "READING";
'590 INPUT A(I)
```

ANALYZE (CONTINUED)

```
1600 IF I=3 THEN 1650
1610 GO TO 1630
1620 LET A(I)=-1
1630 PRINT
1640 RETURN
1650 PRINT "TEMP IN C";
1660 INPUT T
1670 PRINT
1680 GO TO 1640
1690 PRINT "THESE RESULTS FOR I.D.O.D. ARE IMPOSSIBLE,RECHECK."
1700 RETURN
1710 IF A(6)<=50 THEN 1750
1720 PRINT
1730 IF A(6)<250 THEN 1800
1740 IF A(6)>=250 THEN 1880
1750 IF A(6)=-1 THEN 2310
1760 PRINT "THE TOTAL COLIFORM COUNT IS ";A(6);" PER 100 ML.";
1770 PRINT " THE COUNT IS SUFFICIENT FOR CLASS 'A' WATER."
1780 PRINT
1790 GO TO 1930
1800 PRINT "TOTAL COLIFORM COUNT IS CONSIDERED A 'RELIABLE' INDICATOR ";
1810 PRINT "AS TO THE POSSIBLE PRESENCE OF BACTERIAL PATHOGENS ...";
1820 PRINT "THEIR PRESENCE INDICATES INADEQUATE WASTE TREATMENT.";
1830 PRINT "SINCE THE TOTAL COUNT IS ";A(6);" PER 100 ML., THIS ";
1840 PRINT "BODY OF WATER IS LIMITED TO BATHING AND IS UNACCEPTABL
1850 PRINT "FOR PUBLIC WATER SUPPLY."
1860 PRINT
1870 GO TO 1930
1880 PRINT "TOTAL COLIFORMS ARE CONSIDERED 'RELIABLE' INDICATORS ";
1890 PRINT "AS TO THE POSSIBLE PRESENCE OF BACTERIAL PATHOGENS...";
1900 PRINT "SINCE THE TOTAL COUNT IS ";A(6);" PER 100ML. ,THIS BODY ";
1910 PRINT "OF WATER IS UNFIT FOR HUMAN CONTACT."
1920 PRINT
1930 IF A(7)>0 THEN 2000
1940 IF A(7)=-1 THEN 2060
1950 PRINT "THIS BODY OF WATER PROBABLY HAS NO RECENT FECAL ";
1960 PRINT "CONTAMINATION. HOWEVER, IF THE TOTAL COLIFORM COUNT ";
1970 PRINT "IS >50 PER 100 ML., ANOTHER FECAL COUNT IS ADVISED."
1980 PRINT
1990 GO TO 2060
2000 PRINT "THE PRESENCE OF FECAL COLIFORMS IN WATER INDICATES ";
2010 PRINT "RECENT FECAL CONTAMINATION. SINCE THE FECAL COUNT WAS ";
2020 PRINT "REPORTED AS ";A(7);" PER 100 ML., THIS BODY OF WATER IS "
2030 PRINT "UNFIT FOR PUBLIC WATER SUPPLY."
2040 PRINT
2050 GOTO 2210
2060 IF A(9)<0.015 THEN 2120
2070 PRINT "PHOSPHATES ARE PRESENT IN SUFFICIENT AMOUNTS,";A(9);
2080 PRINT " PPM, THAT COULD 'TRIGGER' AN ALGAL BLOOM,IF OTHER ";
2090 PRINT "CONDITIONS ARE RIGHT."
```

ANALYZE (CONTINUED)

```
2100 PRINT
2110 GO TO 2310
2120 PRINT "PHOSPHATES,REPORTED TO BE PRESENT IN QUANTITIES OF ";A(9);
2130 PRINT " PPM, SEEM SUFFICIENTLY LOW TO PARTIALLY INHIBIT ";
2140 PRINT "THE PRODIGIOUS GROWTHS OF ALGAE. IF ALGAE DOES PERSIST ";
2150 PRINT "IN LARGE NUMBERS, CHECK THE FOLLOWING:"
2160 PRINT TAB(13);"NITRATE-NITROGEN"
2170 PRINT TAB(13);"NITRITE-NITROGEN"
2180 PRINT TAB(13);"AMMONIA COMPOUNDS"
2190 PRINT
2200 GO TO 2310
2210 IF A(8)=-1 THEN 2060
2220 IF A(7)/A(8)>1 THEN 2270
2230 PRINT "SINCE FECAL STREP EQUALS ";A(8);" THE CONTAMINATION ";
2240 PRINT "IS LIKELY ANIMAL WASTE."
2250 PRINT
2260 GO TO 2060
2270 PRINT "SINCE FECAL STREP EQUALS ";A(8);" THE CONTAMINATION ";
2280 PRINT "IS LIKELY HUMAN WASTE."
2290 PRINT
2300 GO TO 2060
2310 END
```

STR-CLAS

STR-CLAS is a stream classification program using New Hampshire standards established January 1, 1970.* **See Table 1.** at end of this appendix. The parameters for the classification are; ph, DØ, TURBIDITY, HYDRØCARBON (ØIL), CØLIFØRM, FECAL CØLIFØRM, and FECAL STREP. By inputting the above parameters from any site study, the output will consist of a classification (A,B,C,D) per parameter. The lowest classification being the stream classification at that site.

A subprogram "STREAM 1" calculates volume of flow and another subprogram "SATTABLE" provides a table of DO saturations from 0° to 50° C for checking your results. A basic description of the final classification is also available.

A "RUN" and "LIST" follows.

---

* This program will be revised to use Federal Standards.

```
RUN

STR-CLAS  09 AUG 70  20:46


 THIS PROGRAM CLASSIFIES WATER PER SITE BY N.H.STANDARDS.


LOCATION ? WINNESQUAM RIVER
DATE OF TEST ? 7-24-70
SITE # ? 3

DO YOU HAVE A PH READING? YES
READING? 6.2

DO YOU HAVE A DISSOLVED OXYGEN (D.O.) READING? YES
READING? 4
WATER TEMP IN C? 13

DO YOU HAVE A TURBIDITY READING? YES
READING? 22

DO YOU HAVE A HYDROCARBON (OIL) FACTOR? NO

DO YOU HAVE A COLIFORM COUNT PER ML.? YES
READING? 33766

DO YOU HAVE A FECAL COLIFORM READING? YES
READING? 250

DO YOU HAVE A FECAL STREP READING? YES
READING? 100

DO YOU HAVE A FLOW CALCULATION TO MAKE? NO
DO YOU HAVE THE VOLUMETRIC VALUE ALREADY? YES
VALUE? 385.1
```

```
SOURCE: NEW HAMPSHIRE WATER SUPPLY AND POLLUTION CONTROL
COMMISSION.          JAN.1,1970.

NOTE: THE FINAL CLASSIFICATION IS THE LOWEST CLASS NOTED BELOW!

RESULTS OF WATER CLASSIFICATION FOR SITE  3  ON WINNESQUAM RIVER FOR
7-24-70


A PH OF  6.2  INDICATES CLASS C WATER.

A D.O. OF  4  INDICATES CLASS D WATER.

A TURBIDITY READING OF  22  INDICATES CLASS B OR C WATER.

     COMMENT:NON-TROUT STREAM ACCEPTABILITY.

A TOTAL COLIFORM READING OF  33766  PER 100 ML.
INDICATES CLASS C OR D WATER.


               COMMENT:
     ANY FECAL COLIFORM OR FECAL STREP READINGS ( YOURS
     ARE  250  AND  100 ) INDICATES RECENT
     CONTAMINATION BY WARM BLOODED ANIMALS.
     THIS CONTAMINATION IS LIKELY HUMAN WASTE.

ALL OF THIS IS BEING CARRIED ALONG AT  385.1  FT↑3/SEC.



DO YOU WISH AN EXPLAINATION OF THE WATER CLASSES (YES/NO)? YES

WHICH CLASS OF WATER (A,B,C,D)? C

 CLASS C: ACCEPTABLE FOR RECREATIONAL BOATING,FISHING,
 AND INDUSTRIAL WATER SUPPLY WITH OR WITHOUT TREATMENT,
 DEPENDING ON INDIVIDUAL REQUIREMENTS. ( THIRD HIGHEST
 QUALITY).

WOULD YOU LIKE ANOTHER CLASS EXPLAINED (YES/NO)? YES
WHICH CLASS OF WATER (A,B,C,D)? D

 CLASS D: AESTHETICALLY ACCEPTABLE. SUITABLE FOR CERTAIN
 INDUSTRIAL PURPOSES, POWER AND NAVIGATION. (LOWEST ALL-
 OWABALE QUALITY NOW LESS THAN 1/2 MILE IN ENTIRE STATE).

WOULD YOU LIKE ANOTHER CLASS EXPLAINED (YES/NO)? NO

DO YOU WISH A TABLE OF THEORETICAL D.O.SATURATION FROM 0 TO 50 CENT.?
```

THEORETICAL D.O.SATURATION TABLE FROM 0 TO 50 CENT.

TEMP	THEORETICAL D.O.
0	14.6
1	14.2
2	13.8
3	13.5
4	13.1
5	12.8
6	12.5
7	12.2
8	11.9
9	11.6
10	11.3
11	11.1
12	10.8
13	10.6
14	10.4
15	10.2
16	10
17	9.7
18	9.5
19	9.4
20	9.2
21	9
22	8.8
23	8.7
24	8.5
25	8.4
26	8.2
27	8.1
28	7.9
29	7.8
30	7.6
31	7.5
32	7.4
33	7.3
34	7.2
35	7.1
36	7
37	6.9
38	6.8
39	6.7
40	6.6
41	6.5
42	6.4
43	6.3
44	6.2
45	6.1
46	6
47	5.9
48	5.8
49	5.7
50	5.6

STR-CLAS

```
100 PRINT
110 SUB STREAM1;SATTABLE
120 MARGIN 70
130 '
140 ' WATER CLASSIFICATION PROGRAM FOR NEW HAMPSHIRE.
150 '
160 ' WRITTEN DURING WATER POLLUTION PROGRAM - SUMMER '70
170 PRINT " THIS PROGRAM CLASSIFIES WATER PER SITE BY N.H.STANDARDS."
180 PRINT
190 PRINT
200 PRINT "LOCATION ";
210 INPUT L$
220 PRINT "DATE OF TEST ";
230 INPUT D$
240 PRINT "SITE # ";
250 INPUT S1
260 LET I=0
270 PRINT
280 PRINT "DO YOU HAVE A PH READING";
290 GOSUB 2510
300 PRINT "DO YOU HAVE A DISSOLVED OXYGEN (D.O.) READING";
310 GOSUB 2510
320 PRINT "DO YOU HAVE A TURBIDITY READING";
330 GOSUB 2510
340 PRINT"DO YOU HAVE A HYDROCARBON (OIL) FACTOR";
350 GOSUB 2510
360 PRINT "DO YOU HAVE A COLIFORM COUNT PER ML.";
370 GOSUB 2510
380 PRINT "DO YOU HAVE A FECAL COLIFORM READING";
390 GOSUB 2510
400 PRINT "DO YOU HAVE A FECAL STREP READING";
410 GOSUB 2510
420 PRINT "DO YOU HAVE A FLOW CALCULATION TO MAKE";
430 INPUT R$
440 IF R$="YES" THEN 510
450 PRINT "DO YOU HAVE THE VOLUMETRIC VALUE ALREADY";
460 INPUT A$
470 IF A$="NO" THEN 530
480 PRINT "VALUE";
490 INPUT F
500 GO TO 530
510 GOSUB #1
520 '
530 ' A(1)=PH   A(2)=D.O.   A(3)=TURBIDITY   A(4)=OIL   A(5)=COLIFORM
540 ' A(6)=FECAL COLIFORM   A(7)=FECAL STREP
550 '
560 LET I=1
570 IF A(I)=-1 THEN 710
580 IF A(I)>8.5 THEN 640
590 IF A(I)>8 THEN 660
```

STR-CLAS (CONTINUED)

```
600 IF A(I)>6.5 THEN 680
610 IF A(I)>6 THEN 700
620 GOSUB 2200
630 GO TO 710
640 GOSUB 2200
650 GO TO 710
660 GOSUB 2180
670 GO TO 710
680 GOSUB 2220
690 GO TO 710
700 GOSUB 2180
710 LET I=2
720 IF A(I)=-1 THEN 870
730 FOR J=0 TO 50
740 READ S(J)
750 NEXT J
760 DATA 14.6,14.2,13.8,13.5,13.1,12.8,12.5,12.2,11.9,11.6,11.3,11.1
770 DATA 10.8,10.6,10.4,10.2,10.0,9.7,9.5,9.4,9.2,9.0,8.8,8.7,8.5
780 DATA 8.4,8.2,8.1,7.9,7.8,7.6,7.5,7.4,7.3,7.2,7.1,7.0,6.9
790 DATA 6.8,6.7,6.6,6.5,6.4,6.3,6.2,6.1,6.0,5.9,5.8,5.7,5.6,5.5
800 IF A(I)>.75*S(T) THEN 840
810 IF A(I)> 5 THEN 860
820 GOSUB 2200
830 GO TO 870
840 GOSUB 2220
850 GO TO 870
860 GOSUB 2180
870 LET I=3
880 IF A(I)=-1 THEN 1010
890 IF A(I)<5 THEN 940
900 IF A(I)<10 THEN 960
910 IF A(I)<25 THEN 990
920 GOSUB 2200
930 GO TO 1010
940 GOSUB 2140
950 GO TO 1010
960 GOSUB 2240
970 GOSUB 2280
980 GO TO 1010
990 GOSUB 2240
1000 GOSUB 2300
1010 LET I=4
1020 IF A(I)=-1 THEN 1110
1030 IF A(I)=1 THEN 1080
1040 IF A(I)=2 THEN 1100
1050 PRINT "INPUT EITHER 1 OR 2 FOR THE OIL FACTOR";
1060 INPUT A(I)
1070 GO TO 1030
1080 GOSUB 2180
1090 GO TO 1110
```

STR-CLAS (CONTINUED)

```
1100 GOSUB 2200
1110 LET I=5
1120 IF A(I)=-1 THEN 1200
1130 IF A(I)<50 THEN 1170
1140 IF A(I)<240 THEN 1190
1150 GOSUB 2260
1160 GO TO 1200
1170 GOSUB 2140
1180 GO TO 1200
1190 GOSUB 2160
1200 PRINT
1210 PRINT TAB(25);
1220 FOR I=1 TO 10
1230 PRINT "*";
1240 NEXT I
1250 FOR I=1 TO 4
1260 PRINT
1270 NEXT I
1280 PRINT "SOURCE: NEW HAMPSHIRE WATER SUPPLY AND POLLUTION CONTROL"
1290 PRINT "COMMISSION.          JAN.1,1970."
1300 PRINT
1310 PRINT "NOTE: THE FINAL CLASSIFICATION IS THE LOWEST CLASS NOTED";
1320 PRINT " BELOW!"
1330 PRINT
1340 PRINT "RESULTS OF WATER CLASSIFICATION FOR SITE ";S1;" ON ";
1350 PRINT L$; " FOR ";D$
1360 PRINT
1370 PRINT
1380 IF A(1)=-1 THEN 1410
1390 PRINT "A PH OF ";A(1);" INDICATES CLASS ";A$(1);" WATER."
1400 PRINT
1410 IF A(2)=-1 THEN 1440
1420 PRINT "A D.O. OF ";A(2);" INDICATES CLASS ";A$(2);" WATER."
1430 PRINT
1440 IF A(3)=-1 THEN 1500
1450 PRINT "A TURBIDITY READING OF ";A(3);" INDICATES CLASS ";A$(3);
1460 PRINT " WATER."
1470 IF A(3)<10 THEN 2110
1480 IF A(3)<25 THEN 2110
1490 PRINT
1500 IF A(4)=-1 THEN 1590
1510 IF A(4)=1 THEN 1560
1520 PRINT "A DEFINITE HYDROCARBON (OIL) OBSERVATION INDICATES CLASS";
1530 PRINT " D WATER."
1540 PRINT
1550 GO TO 1590
1560 PRINT "A SLIGHT HYDROCARBON (OIL) FILM INDICATES AT BEST CLASS";
1570 PRINT " C WATER."
1580 PRINT
1590 IF A(5)=-1 THEN 1630
```

STR-CLAS (CONTINUED)

```
1600 PRINT "A TOTAL COLIFORM READING OF ";A(5);" PER 100 ML."
1610 PRINT "INDICATES CLASS ";A$(5);" WATER."
1620 PRINT
1630 IF A(6)=-1 THEN 1740
1640 PRINT
1650 PRINT TAB(15);"COMMENT:"
1660 PRINT TAB(5);"ANY FECAL COLIFORM OR FECAL STREP READINGS ( YOURS'
1670 PRINT TAB(5);"ARE ";A(6);" AND ";A(7);") INDICATES RECENT"
1680 PRINT TAB(5);"CONTAMINATION BY WARM BLOODED ANIMALS."
1690 IF A(7)=-1 THEN 1740
1700 IF A(6)/A(7)>1 THEN 1730
1710 PRINT TAB(5);"THIS CONTAMINATION IS LIKELY ANIMAL WASTE."
1720 GO TO 1740
1730 PRINT TAB(5);"THIS CONTAMINATION IS LIKELY HUMAN WASTE."
1740 PRINT
1750 PRINT "ALL OF THIS IS BEING CARRIED ALONG AT ";F;" FT↑3/SEC."
1760 FOR J=1 TO 5
1770 PRINT
1780 NEXT J
1790 PRINT "DO YOU WISH AN EXPLAINATION OF THE WATER CLASSES (YES/NO)";
1800 INPUT R$
1810 IF R$="YES" THEN 1830
1820 GO TO 2030
1830 PRINT
1840 PRINT "WHICH CLASS OF WATER (A,B,C,D)";
1850 INPUT L$
1860 IF L$="A" THEN 1910
1870 IF L$="B" THEN 1940
1880 IF L$="C" THEN 1970
1890 GOSUB 2320
1900 GO TO 1990
1910 PRINT
1920 GOSUB 2370
1930 GO TO 1990
1940 PRINT
1950 GOSUB 2410
1960 GO TO 1990
1970 PRINT
1980 GOSUB 2460
1990 PRINT
2000 PRINT "WOULD YOU LIKE ANOTHER CLASS EXPLAINED (YES/NO)";
2010 INPUT R$
2020 IF R$="YES" THEN 1840
2030 PRINT
2040 PRINT "DO YOU WISH A TABLE OF THEORETICAL D.O.SATURATION FROM";
2050 PRINT " 0 TO 50 CENT.";
2060 INPUT A$
2070 IF A$="YES" THEN 2090
2080 STOP
2090 GOSUB #2
```

STR-CLAS (CONTINUED)

```
2100 STOP
2110 PRINT
2120 PRINT TAB(5);"COMMENT:";B$(3)
2130 GO TO 1490
2140 LET A$(I)="A"
2150 RETURN
2160 LET A$(I)="B"
2170 RETURN
2180 LET A$(I)="C"
2190 RETURN
2200 LET A$(I)="D"
2210 RETURN
2220 LET A$(I)="A OR B"
2230 RETURN
2240 LET A$(I)="B OR C"
2250 RETURN
2260 LET A$(I)="C OR D"
2270 RETURN
2280 LET B$(I)="TROUT STREAM ACCEPTABILITY."
2290 RETURN
2300 LET B$(I)="NON-TROUT STREAM ACCEPTABILITY."
2310 RETURN
2320 PRINT
2330 PRINT " CLASS D: AESTHETICALLY ACCEPTABLE. SUITABLE FOR CERTAIN"
2340 PRINT " INDUSTRIAL PURPOSES, POWER AND NAVIGATION. (LOWEST ALL-"
2350 PRINT " OWABALE QUALITY NOW LESS THAN 1/2 MILE IN ENTIRE STATE)."
2360 RETURN
2370 PRINT " CLASS A: POTENTIALLY ACCEPTABLE FOR PUBLIC WATER SUPPLY"
2380 PRINT " AFTER DISINFECTION. NO DISCHARGE OF SEWAGE OR OTHER"
2390 PRINT " WASTES. (QUALITY UNIFORMLY EXCELLENT)."
2400 RETURN
2410 PRINT "CLASS B: ACCEPTABLE FOR BATHING AND RECREATION,FISH"
2420 PRINT "HABITAT AND PUBLIC WATER SUPPLY AFTER ADEQUATE TREATMENT."
2430 PRINT " NO DISPOSAL OF SEWAGE OR WASTES UNLESS ADEQUATELY TREATED."
2440 PRINT " (HIGH AESTHETIC VALUE.)"
2450 RETURN
2460 PRINT " CLASS C: ACCEPTABLE FOR RECREATIONAL BOATING,FISHING,"
2470 PRINT " AND INDUSTRIAL WATER SUPPLY WITH OR WITHOUT TREATMENT,"
2480 PRINT " DEPENDING ON INDIVIDUAL REQUIREMENTS. ( THIRD HIGHEST"
2490 PRINT " QUALITY)."
2500 RETURN
2510 LET I=I+1
2520 INPUT R$
2530 IF R$="NO " THEN 2640
2540 IF R$="YES" THEN 2590
2550 PRINT "INCORRECT FORMAT. PLEASE TYPE YES OR NO."
2560 PRINT " DO YOU HAVE A READING";
2570 INPUT R$
2580 GO TO 2530
2590 IF I=4 THEN 2700
```

STR-CLAS (CONTINUED)

```
2600 PRINT "READING";
2610 INPUT A(I)
2620 IF I=2 THEN 2670
2630 GO TO 2650
2640 LET A(I)=-1
2650 PRINT
2660 RETURN
2670 PRINT "WATER TEMP IN C";
2680 INPUT T
2690 GO TO 2650
2700 PRINT "(1) SLIGHT OIL FILM OR (2) OIL SLICK";
2710 INPUT A(I)
2720 GO TO 2650
2730 END
```

STREAM1

```
100 DIM D(20),H(20),I(20)
110 PRINT
120 PRINT
130 PRINT TAB(15);"STREAM CROSSECTION CALCULATION."
140 PRINT
150 PRINT
160 PRINT "WIDTH OF STREAM (F,I)";
170 INPUT W,W5
180 LET W=W+W5/12
190 PRINT "HOW MANY DEPTH READINGS WERE TAKEN";
200 INPUT R
210 PRINT"DISTANCE FROM SHORE TO FIRST MEASUREMENT(FT.) AND";
220 PRINT " DEPTH (F,I)";
230 INPUT D(1),H(1),I(1)
240 LET H(1)=H(1)+I(1)/12
250 LET W1=D(1)
260 FOR J=2 TO R
270 PRINT "DISTANCE(F),DEPTH(F,I)";
280 INPUT D(J),H(J),I(J)
290 LET H(J)=H(J)+I(J)/12
300 LET W1=W1+D(J)
310 NEXT J
320 PRINT "DISTANCE FROM LAST DEPTH TO SHORE";
330 INPUT D(R+1)
340 LET W1=W1+D(R+1)
350 IF W1=W THEN 430
360 PRINT
370 PRINT "ERROR IN WIDTH MEASUREMENT."
380 PRINT
390 PRINT "DO YOU WISH TO CONTINUE";
400 INPUT R$
410 IF R$="YES" THEN 430
420 STOP
430 LET T=.5*D(1)*H(1)
440 LET W=W1
450 FOR I=1 TO R-1
460 IF H(I+1)>H(I) THEN 500
470 LET T=T+.5*(H(I)-H(I+1))*D(I+1)+D(I+1)*H(I+1)
480 NEXT I
490 GO TO 520
500 LET T=T+.5*(H(I+1)-H(I))*D(I+1)+H(I)*D(I+1)
510 GO TO 480
520 LET T=T+.5*D(R+1)*H(R)
530'VELOCITY
540 PRINT
550 PRINT TAB(15);"AVERAGE VELOCITY CALCULATION."
560 PRINT
570 PRINT "HOW MANY TRIALS WERE CONDUCTED";
580 INPUT K
590 LET V=0
```

STREAM1 (CONTINUED)

```
600 FOR J=1 TO K
610 PRINT "DISTANCE BETWEEN POINTS(FT.,IN.)";
620 INPUT F(J),I(J)
630 LET F(J)=F(J)+I(J)/12
640 PRINT "TIME OF FLOAT(SEC.)";
650 INPUT S(J)
660 LET V=F(J)/S(J)+V
670 NEXT J
680 LET V=V/K
690 PRINT "WAS THE STREAM 1)SMOOTH OR 2) ROUGH BOTTOMED";
700 INPUT A
710 IF A=2 THEN 740
720 LET V=V*.9
730 GO TO 750
740 LET V=V*.8
750 LET F=T*V
760 LET F=INT(F+.5)
770 PRINT
780 PRINT "FOR A MORE COMPLETE ANALYSIS,USE THIS DATA IN 'STREAM'.
790 PRINT
800 RETURN
810 END
```

SATTABLE

```
100 DIM S(51)
110 ' THEORETICAL D.O. SATURATION TABLE.
120 PRINT
130 PRINT
140 PRINT "THEORETICAL D.O.SATURATION TABLE FROM 0 TO 50 CENT."
150 PRINT
160 PRINT TAB(26);"THEORETICAL"
170 PRINT TAB(5);"TEMP";TAB(30);"D.O."
180 PRINT
190 FOR I=0 TO 50
200 IF I>9 THEN 260
210 PRINT TAB(6);I;
220 IF S(I)<10 THEN 280
230 PRINT TAB(28);S(I)
240 NEXT I
250 RETURN
260 PRINT TAB(5);I;
270 GO TO 220
280 PRINT TAB(29);S(I)
290 GO TO 240
300 END
```

Appendix 2 Draft

Implimentation

The implementation of the activities depend on the school's ability to handle several problems, namely: cost, scheduling, and motivation. These problems are interrelated at most schools; therefore, they must be resolved as the program proceeds. Beginning with a small group of interested administrators, teachers and students seems to be a good approach. A club or single course offering, may be as far as a school can proceed in the first year. The schools listed in the preface have programs underway or are beginning programs. Furthermore, they are grouped into clusters which meet monthly, carry on interschool activities, and support the implimentation of this program in their region. The organized regions are: Central New Hampshire, Southern New Hampshire - Vermont, Eastern Massachusetts, Central Massachusetts, Northern Massachusetts, New York - Pennsylvania - New Jersey, Washington (D.C.) and South Carolina - Georgia. Any school listed in the preface may be contacted to obtain the cluster coordinator's name.

The sections below deal with the various problems of implimentation.

A Cost

The expense involved in beginning a program can be minimized in several ways; costs are increased by equipment, travel, and books and references. Equipment for all but a few activities is not specialized and probably already exists in the various school laboratories. For example, any of the chemical analyses may be made in the lab. Usually though, this makes testing slow, inconvenient, and remote for the test site. Field test kits which are modular can be obtained to perform selected tests; an elementary kit which contains tests for DO, temperature, turbidity, pH, chlorine, phosphate, sulphate, and nitrate as sufficient to tests (bacteria) do require equipment which may not be on hand; consult with the staff of your local hospital, county health department and sewage treatment plant. Usually an arrangement may be worked out.

If your school is a non-profit enterprize it qualifies for U.S. goverment surplus. To obtain information on the location of such surplus depots, contact your state education department. Local industry has been found to be particularly helpful; money may not be too easily obtained but often slightly used equipment or materials will be made available. If you make your needs known through news media and at community meetings and fairs almost any thing can happen. Students at Germantown Academy have helicopter service available for aerial photography as a result of their activities in mapping and monitoring the Wissachickon Creek.

Much of the equipment listed in the activities may be made by hand. If students and teachers work together on this a great deal of equipment may be made in a short time. After the making of equipment leads to new and better methods of inquiry.

B. Scheduling

Teachers have noted that informal arrangements with other teachers allow the greatest flexibility when the school is unable to provide adequate scheduled time. The sports department arrangements for team games usually may be duplicated if the importance of academic pursuits can be established. Past experience indicates that as the school gains recognition in the community for its achievements, the difficulty in getting time for activities diminishes rapidly. Activities such as G and H in Chapter 4 are good beginning places to arouse community interest.

C. Motivation

Helping to build the necessary pollution group teachers, students, administrators and parents will be an important function that you must perform. The pollution problems which we face today are, in themselves grave enough to motivate people to action. Therefore, in many cases all that needs to be supplied is a vehicle for expressing and focusing this action. This can very often be accomplished through a club, the planning and presentation of an assembly program, or a variation of an earth day program.

Any of the above activities may serve to allow the students, faculty, administration, and even the parents to become involved and interested in some particular facet of our pollution problems. Once interest and activity have begun there are several means of aiding in its continuance.

School administrators are particularly fond of anything which gains favorable publicity for the school. Most of the above mentioned activities will produce this in the form of newspaper articles and radio and T.V. newscasts. All that you need do is be sure to advise them of what you are up to beforehand.

We have found that one factor which aids in the sustained effort of the students is to make them aware of your belief that they are capable of making significant contributions to the community at large. They do possess the initiative and curiosity to determine problems, conduct research, and translate the information into meaningful conclusions and it is important that you make your awareness of this known to them. A published statement to this effect on the part of the faculty, the publication of a student journal, or the submission of their data and conclusions to the appropriate public agencies serves to substantiate this in the minds of the students.

Since students enjoy this activity orientated approach and, at the same time, learn more through it, other teachers will want to know what you are doing. Do not be afraid to explain it to them or even better, invite them to participate in the activities along with the students. Your success should provide the necessary motivation for them to try it also.

It is wise to motivate as many parents as possible in what you are doing also. They are naturally curious about what their children are doing in school so invite them to participate or at least arrange for a demonstration for them. They may prove to be an important resource for you in terms of information, equipment, and help in transportation which they can provide.

Limitations

There are a number of possible trouble spots which may pop up during the implementation of these activities. A foreknowledge of these problem areas will, in most cases, be all that is needed to avoid them. In general the problems seem to fall into three categories: time and transportation, methods and equipment, and dealing with others.

A Time and Transportation

1. Most activities in this guide are designed to last an hour and a half, however, many do require more time to accomplish. For one of the filming activities, for example, students camped overnight on Cardigan Mountain in order to film the sunrise.
2. Some lab experiments required by these activities take a long time to get results. The B.O.D. test, for example, requires five days before results can be obtained. Thus it may become a test of your student's patience.
3. Some people will have difficulty locating suitable streams or lakes for their activities. Streams with the easily monitored depth, rate of flow, width, suitable access points, etc. are not always close by the school.
4. Transporting a large class to and from a sight may pose problems in simply obtaining permission to use school bus, missing lunch, parents' permissions, a driver for

school bus, box lunches or money for lunches. Methods must be devised to overcome such obstacles. Often making friends with the janitors, cafeteria people and bus drivers is the key.

B Methods and Equipment

1. After gaining permission to leave school with your class and having organized all these details, do not forget to advise parents that the students may be required to wade in streams and grovel in the dirt. Students' clothes may become somewhat soiled.
2. Also before leaving the school, be sure you have all the equipment necessary for the activity. This reduces transportation costs and total time required immensely.
3. Students should be well versed in the care of equipment in the field where it is much more difficult to keep it dry and clean.
4. Where sterile procedures are required in the field, special care must be taken, for the chances of contamination seem to increase in proportion to the distance from the lab.
5. There is some danger involved when students are dealing with sewage wastes. Hip boots and rubber gloves are sometimes a necessity.
6. We have found some keys especially difficult to use. Keep looking for one that is less vague than the one you are

presently using.

7. If the cost of some of the equipment is prohibitive in your case, please use Appendix 2 on Implementation to help remedy these difficulties.

C Dealing with Owhers

1. When taking relatively large groups to confined places (a city manager's office, for example) or a private owned area (such as a farm) it is advisable to be sure the persons or persons involved understand the size and age level of the group beforehand so that they will be prepared.
2. Always be sure to arrange your appointments well in advance if possible.
3. If you arrange an interview be sure to list your questions before you arrive. In general people are willing to cooperate but their time is limited.
4. Always gain permission to use private land even if you are only using it as access to a lake, river, or stream.
5. Be sure to arrange for the protection of equipment if it must be left in place for any length of time. Many experiments have been disrupted or completely destroyed by curious or unknowing outsiders. Experience has shown that experiments placed in driveways or parking lots are particularly vulnerable.
6. Since these activities are concerned with water pollution, you must be prepared at some point to deal with the pol-

luters themselves. To what extent you are willing to incur their wrath is not only a test of your own moral fortitude, but your school's as well.

Evaluation

Accountability is an essential ingredient in all educational programs. Effective fulfillment of this parameter requires careful planning accompanied by an appropriate evaluation. This may seem antagonistic to an approach consisting of activities which are defined no more than necessary to initiate thinking processes and promulgated through questions which may lead to unexpected outcomes. However, planning and evaluation are "musts" if any success or measure of success is to be obtained.

Organizational and evaluative aids are included in each section of the activity outlines. The introductions state general objectives. The questions provide direction (but not in a dictational manner) and suggest behavioral changes which might be observed for evaluative purposes. Procedures, past examples and limitations include guidance in organizing the activity.

The foundation for planning and evaluation must begin at the time the activity is selected. This is accomplished by identifying the desired outcomes or objectives on paper in behavioral form. General statements such as the following are of limited use:

a. The student will understand the effects of chemicals on a specific ecosystem.

b. The students will develop an appreciation of the economic factors associated with pollution.

However, behavioral statements which not only designate the desired outcome but also identify a resulting behavior and the conditions under which it is to be observed and evaluated can be extremely useful in planning and evaluative efforts. For example:

c. When provided alkalinity, iron and dissolved oxygen data for a body of water, the student correctly describes one or more biological effects which might be observed at the site.

These objectives should include not only cognitive or psychomotor categories but also affective behavior. (See d. above) While the former are significant, the urgency of current pollution justifies emphasis of attitudes, values and motivation. Other than these remarks, it is not within the scope of this guide to cover thoroughly the philosophy and writing of behavioral objectives. Such information is readily available (see Bibliography) and should be consulted by those who are unfamiliar with behavioral objectives.

As stated earlier, preliminary behavioral objectives should be formulated immediately upon selection of the activity. In addition to serving an evaluative role, they are a source of guildance for planning the unit. However, they must not be allowed to limit innovative approaches to the study.

Once the activity is in progress, the preliminary objectives should be modified. If the activity is allowed to progress creatively, many unexpected desirable goals will emerge. They must not be ignored because they were not recognized at the start. To the contrary, such goals should be incorporated into the listing of objectives. It may be necessary to discard some of the preliminary behavioral objectives if they are found inappropriate. In this way the objectives evolve throughout the entire activity. As such they become representative of the activity rather than a list of idealistic goals developed for a file.

The revised behavioral objectives are used as guides in the formulation of an evaluative tool appropriate to the study. If properly constructed the criteria and methods of evaluation will be stated within each objective.

In addition to fulfilling immediate planning and evaluative needs, the resulting behavioral objectives and data provide valuable tools for modifying the activity for future students.

Evaluation

1. Eiss, A., Behavioral Objectives in the Affective Domain, National Science Teachers Association, Washington, D.C.(1969) This useful guide for writing behavioral objectives includes specific examples encompassing psychomotor, cognitive and affective domains.
2. Koran, J., etal, How to Write Behavioral Objectives in Science Instruction, National Science Teachers Association, Washington, D.C. (1969). A discussion of the theory and expression of objectives concerned with affective behavior.
3. Mager, R.F., Preparing Instructional Objectives, Fearon Publishers, Palo Alto, Calif. (1962). A branch programmed text for instruction in the writing of objectives.

Appendix 5 Draft

Bibliography

During this age of the "information explosion," it is imperative that students learn to use many appropriate sources while researching a particular problem. For this reason a listing of those books and pamphlets found particularly useful by teachers and students in the study of water pollution during the 1969 and 1970 summer programs and the 1969-1970 school year are included. It is hoped that most of the publications listed under Core References will be made available to students while studying water pollution. The references listed under Additional References are also excellent, but due to prior consideration on the technical level should probably be added only after the Core References have been secured.

This bibliography is by no means comprehensive. Hopefully, current periodicals, state and federal water surveys, for your area, and local library resources will supplement this reference listing.

A. Core References

The following set of publications will provide a working reference source for any class, upper elementary through twelfth grade. It is recommended that multiple copies of the asterisked publications be obtained, depending on class size and grade level. Those references with one asterisk (*) should be purchased in multiple copies for elementary through eighth grade use. The double asterisk (**) indicates that multiple copies could best be used for a ninth through twelfth grade situation.

Billings, W. D., Plants, Man, and the Ecosystem,

2nd edition, Fundamentals of Botany Series, Wadsworth Publishing Co., Belmont, California, 1970, 160 p. This paperback can introduce ecological concepts to 9-12th graders and contains a section concerning man's affects on the environments.

2. Carvajal, J., Munzer, M.E., Conservation Education--a Selected Bibliography, The Interstate Printers and Publishers, Danville, Ill, 1968, 98 p. An annotated bibliography dealing with not only water but air, population, and land conservation.
3. Frost, T.P., The Galloping Ghost of Eutrophy, Society for the Protection of New Hampshire Forests, 5 South State St., Concord, N. H., 1968, 36 p., $20. A well written pamphlet on the problem of eutrophication.
4. Leopold, L.B., Davis, K.S., Water, Life Science Library, Time Incorporated, N.Y., 1966, 200 p. A well illustrated book covering water use and hydrology. Particularly useful for lower grade use.
5. **McKee, J.E., Wolf, H.W., Water Quality Criteria, 2nd edition, Water Quality Control Board, Sacramento, Calif., (1963), 548 p. An excellent reference, although dated, on chemical, biological, radioactive, and pesticide pollutants. Each pollutant is explained and many toxicity levels are listed. 3827 references are listed.
6. **Needham, J.G., Needham, P.R., A Guide to the Study of Fresh-Water Biology, Holden-Day, Inc., 500 Sansome St., San Francisco,

Calif., 1969. 108 p. An excellent reference book for any fresh-water biology work. Thoroughly illustrated with a good section of collection and quipment!

7. Ward, R.C., Principles of Hydrology, McGraw-Hill, N.Y., 1967. Easily readable for high school level. Stimulating ideas for activities.
8. Environmental Education for Everyone--Bibliography of Curriculum Materials for Environmental Studies, National Science Teachers Association, 1201 Sixteenth St., N. W., Washington, D.C., 20036, 1970, 36 p., $75. The most comprehensive bibliography reviewed to date. Includes programs in environmental education curriculum guides, textbooks, experiments, enrichment readings, periodical listings, film strips, film lists, and other invaluable materials for environmental studies.
9. Simplified Laboratory Procedures for Wastewater Examination, WPCF Publication #18, Water Pollution Control Federation, 3900 Wisconsin Ave., Washington, D.C., 30016, 1969, 62 p., $3.00. Simplified Standard Method tests for physical and chemical examination of water. Best for use in grades 9-12.
10. **Standard Methods for the Examination of Water and Wastewater, 13th ed., APHA, AWWA, WPCF, published by American Public Health Association, 1740 Broadway, New York, N.Y. (1971). An indispensible technical reference which includes test procedures and explanations of dissolved solids and gases found in water. The biology section includes collection methods and diagrams of

organisms. The 13th edition will not be ready for sale until February 1971 at which time the cost will be in the area of $20.

The following publications may be purchased through the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402.

1. *Baldwin, H.L., McGuinness, C.L., A Primer on Ground Water, 1966, 26 p., $.25.This pamphlet explains ground water and groundwater resources competently for 7-12th grade use.
2. *Leopold, L.B., Langbein, W.B., A Primer on Water, 1966, 50p. $.35. Good introductory pamphlet on hydrology and water use. Good for 7-12th grade use. Includes a glossary.
3. A Primer on Waste Water Treatment, 1969, 24 p., $.55. A clearly written pamphlet concerning the methods and problems of waste water treatment. Good for 7-12th grade use.
4. Water, The Yearbook of Agriculture-1955, 751 p., $2.00. Numerous papers on water source and use. An excellent book for the money...if it is still available from the Superintendent.
5. The Practice of Water Pollution Biology, 1969, 281 p., $1.50. This paperback covers areas such as aquatic environments, organic wastes, toxic materials, acid mine and radioactive wastes, eutrophication, marine environments, water and waste treatment, and nuisance organisms. Large reference section.
6. Ingram, W.M., MacKenthum, K.M., Bartsch, A.F., Biological Field Investigative Data for Water Pollution Surveys, 1966, 139 p., $.70.

This paperback has sections on graphical expression of data and organism response to organic pollution. Good references and glossary.

7. Water Quality Criteria, Federal Water Pollution Control Administration, 1968, 234 p., $3.00. This book defines the various uses of water in the U.S., and recommends the various parameter limits for the different water uses. Good references and glossaries included.
8. Public Health Service Drinking Water Standards, 1969, 61 p., $.30. This pamphlet deals with water supply and protection and individual limits for chemical, bacteriological, radioactive, and physical characteristics.

Individual copies of the following three pamphlets may be obtained free from Mellipore Corporation, Bedford, Massachusetts, 01730.

1. Microbiology for the Beginning Student, 1969, 12 p. Basic explanation of the membrane filtration technique and equipment.
2. Experiments in Microbiology, 1969, 45 p. An excellent pamphlet for 7-12th grade use. Procedures and experiments to familiarize students with microorganisms--their occurrence in nature and ways to culture them.
3. Microbiological Analysis of Water, 1969, 25 p. Good procedures and explanations of coliform indicators and other bacteria.

The following three pamphlets may be purchased for $.50 each through Educational Products Division, LaMotte Chemical Products Company, Chestertown, Md., 21620.

1. *Amos, W.H., Limnology, 1969, 39 p. This introduction to the fresh water environment is simply written and can be used by 7-12th graders. Running water and still water and the organisms found in each are discussed.
2. Renn, C.E., A Study of Water Quality, 1968, 46 p. A good pamphlet dealing with the general aspects of water pollution. Usable in 7-12th grade.
3. Renn, C.E., Our Environment Battles Water Pollution, 1969, 32 p. Good paperback, usable in elementary through twelfth grade, dealing with various dissolved solids and gases and their relationship with organisms.

B. Additional References

The following list of references could be extremely beneficial in the study of water pollution. However, due to the price or technical nature, these texts should probably be purchased after the Core References have been obtained.

1. Chorley, R.J. (editor), Water, Earth, and Man, Barnes and Noble, Inc. A good reference on hydrology and water use, capable of being used by 7-12th graders.
2. Foerster, J.W., A Phyco-periphyton Collector, Turtox News, 47-3, p. 82-84, 1969. Describes a simple, easy-to-make periphyton collector. The periphyton is collected on glass microscope slides.
3. McHarg, I.L., Design With Nature, Natural History Press, New York, 1969. An excellent book which deals with the need

for environmental planning as further development (of land) takes place. Best for high school use.

4. Pelczar, M.J., Reid, R.D., Microbiology, McGraw-Hill, N. Y. A microbiology text which includes introductions to the taxonomy, biochemistry, cultivation, control, and ecological role of microorganisms.
5. Pennak, R.W., Fresh-Water Invertebrates of the United States, Ronald Press Co., N. Y., 1953, 769 p. A thorough, technical text.
6. Sawyer, C.N., McCarty, P.L., Chemistry for Sanitary Engineers, 2nd ed., McGraw-Hill, N.Y., 1968, 518 p. A thorough presentation of the theory and methods of sanitation chemistry. This book might best be used as a teacher's reference because a knowledge of elementary chemistry is assumed.
7. Smith, G.M., Fresh-Water Algae of the United States, McGraw-Hill, N.Y., 1950, 719 p. A comprehensive text on algae--collection, preservation, and methods of study.
8. Ward, H.B., Whipple, G.C., Fresh-Water Biology, 2nd edition, John Wiley and Sons, N.Y. The single most comprehensive manual for the identification of aquatic plants and animals.
9. Special Publication Number 1, Sources of Limnological and Oceanographic Apparatus and Supplies, American Society of Limnology and Oceanography. Many specialized items of biological collecting equipment are not available from the usual supply

houses. This publication lists the suppliers. It is available from the secretary of the society.

C. Periodicals

To keep students aware of environmental news, a number of periodicals should be made available for classroom use. The following periodicals were found useful during the 1969-1970 school year:

1. The Conservation Foundation Letter, (monthly), The Conservation Letter, 1717 Massachusetts Ave., N.W., Washington, D.C., 20036, $6/yr. A three-hole punched newsletter capable of being accumulated for reference in a loose-leaf notebook. Deals with current legislation and all types of environmental news. Probably best for high school use.
2. Environmental Science and Technology, (monthly) American Chemical Society, 20th and Northampton Sts., Easton, Pa., 18042, $7./yr. A technical magazine...good for high school use.
3. Environment, (10 issues/yr.), Circulation Dept., Environment, 438 North Skinker Boulevard, St. Louis, Missouri, 63130, $8.50/yr. A well written periodical, dealing in depth with current environmental problems. Capable for use in grades 7-12.

D. Movies

During the 1969-1970 school year, Miss Elizabeth Gage and her students at Northfield School reviewed the following environmental films. The film reviews worked on during the 1970 summer programs at Tilton have not yet been compiled, but will be forthcoming in the newsletters.

Title: "It's Your Decision: Clean Water"

Source: Association Films, Inc.

Regional Film Centers:
600 Grand Avenue, Ridgefield, New Jersey 07657
561 Hillgrove Avenue, LaGrange, Illinois 60525
324 Delaware Avenue, Allegheny County, Oakmont, Pa. 15139

Information: Color, 14 minutes, free loan.

Summary: The movie begins by briefly tracing the development of towns and cities along rivers and streams. It showed how rivers used to be able to handle their pollutional load but with our rapidly growing population, the pollution crisis has become more acute. Animated figures are used to show the basic characteristics of polluted water and how primary and secondary water treatment plants operate.

Appraisal: Because the movie is easy to understand, it could be shown to several different types of audiences. Clean Water would be effective as an introductory film for a pollution course. The film would benefit elementary school students if seen as an introduction to our nations pollution problems. The film would also be very effective if shown in a community where a secondary water treatment plant is needed. It could be shown to the general public too, as a short in a movie theatre for instance.

Title: "Oops, or How Broad Shoulders Polluted the River"

Source: University of Minnesota, Audio-Visual Department, 2037 University Avenue, S.E., Minneapolis, Minnesota 55455.

Information: Black and white (Color: $5.85), 22 minutes

Summary: This movie gave insight into industry's problems in controlling pollution, listing several different aspects such as analyzing wastes, repairing equipment, showing concern for waste treatment plants, and spreading responsibility to everyone. It stressed the importance on competent, well-trained employees. The title refers to a worker, "broad shoulders," who through inattentiveness, poor management, and poor training created a big mess of overflowing tanks of chemicals, petroleum, and suds.

Appraisal: The class felt that this movie was good for our purpose but is best suited for its intended purpose of making industry aware of the problems of pollution and suggesting how these problems can be solved. It was good for our class because we have little opportunity to come in contact with industry, their problems, and attempts to remedy the situation.

Title: "Becket Adventures"

Source: Sid Dupont, Becket Academy, East Haddam, Connecticut

Information: Color, 30 minutes.

Summary: Mr. Dupont visits schools showing films or slides of the canoe trip Becket summer students take down the Connecticut River from the source to the sound. The boys on the trip surveyed points along the river, recording animal and plant life in the area, bottom structure, flow, weather, geology and the condition of the river itself. This information is written in a log which may be obtained from Becket Academy.

Appraisal: Although this film was made by amateurs, we feel it is useful for obtaining a general picture of the condition of the Connecticut. We feel that Mr. Dupont wants others to become aware of the environment in which they live through this movie just as the boys became aware through their trip. We feel that this is a worthwhile movie for students of pollution to see.

Title: "Story of a Lake"

Source: Chevron Chemical Company, Advertising and Public Relations, Ortho Division, 200 Bush Street, San Francisco, California.

Information: Color, 10-15 minutes, free loan (one day)

Summary: The film describes the conditions in a small lake choked with water weed (Elodea) and includes interviews of homeowners who describe the effect of the lake in this condition on their recreational enjoyment of the lake and on property values for lake sites. The people try to control the growth of water weed by raking it out, but find that this offers only temporary control. The lake community calls on the services of a professional herbicide company who spray the lake with the chemical Diquat (a product of the Chevron Company). There are scenes showing the lake being sprayed from a small boat. The effects of the chemical are described in rather general terms ("...attacks green matter and breaks down cell structure..."). The herbicide takes effect in 4-5 days and after 10-14 days the water weed has decomposed. Views of the clean lake are shown and community members are interviewed for their impressions.

Appraisal: The film is clearly selling Diquat, a product of the Chevron Chemical Company, and the biological content of the film is minimal. It is, in our opinion, not as useful for water pollution studies as it might be. One wonders if the herbicide is "harmless to water animals," why the men spraying the water are wearing coveralls and masks while they are working. Further, we wonder specifically what effect the chemical has on cells. . .maybe a letter to the Chevron Company would clear this up for us.

Title: "Membrane Microfiltration: A New Tool for Classroom Science"

Source: Bernard I. Sohn, Educational Division, Millipore Corporation, Bedford, Massachusetts 01730

Also, Tilton has this film to lend by request.

Information: Color, 30 minutes, free loan.

Summary: The movie dealt specifically with Millipore apparatus, its uses in the classroom, in the field, in industry, and in medicine. It also stressed the advantage of the Millipore over previous techniques of filtering by using clever photography. Animated figures representing bacteria describe the filtering process and its usefulness in detecting the presence of micro-organisms.

Appraisal: Although this film was intended for showing to teachers, we feel it should be used as an introduction for students as well. The film is simple yet comprehensive in its coverage of the subject.

Title: " Water: Pattern of Life"

Source: Ohio Department of Natural Resources, Administrative Services Section, 1500 Dublin Road, Columbus, Ohio 43212

Information: Color, Free loan

Summary: This movie told about the sources of, uses of, and problems with the natural water in the state of Ohio. It covered many topics such as the hydrological cycle, and transportation, droughts, flood control, underground water supply, growing population, recreational uses of water, industrial uses of water, reservoirs, and quality control of water. It offered suggestions as how to solve the problems; for example, surveying, control of flood plains, and long-range planning of water use and supply. It also suggested that areas should be divided into watershed basins to control the problems.

Appraisal: This film would be good as an introduction to water pollution or biology because it shows the wide usage of water. It does not, however, deal specifically with much on pollution or control of it. It also is outdated as it speaks of Lake Erie as a valuable source of water, which it was at one time!!

Title: "What Are We Doing to Our World" (in two parts)

Source: University of Minnesota, Audio-Visual Department, 2037 University Avenue, S.E., Minneapolis, Minnesota 55455.

Information: Color, 25 minutes each, $7.20 each reel

Summary: "We are going to have to choose between the advancements of technology. . ." and the necessity of maintaining ecological balances on earth. This film explores some serious consequences of unrestricted growth, pollution, waste and over-population problems.

What was a question of conservation on earth is becoming a question of survival. Experiments such as the one at Hubbard Brook attempt to understand ecological balances and explore some of the unforeseen consequences of man's attempts to make a better world.

Appraisal: An excellent film. . . provokes very good discussion among students. . . It is an unbalanced film from the point of view that it stresses what we are doing to pollute and far less is said about what we might do to prevent pollution. In several places, it is brought out that people will have to re-examine their attitudes and values concerning their relation to the earth environment and this serves to balance the views presented. The spokesman for the Agricultural Chemists presents some interesting arguments about continued use of pesticides.

Title: "Municipal Sewage Treatment Processes"

Source: Communicable Diseases Center, Atlanta, Georgia 30333

Information: Black and White, 13 minutes, Free loan

Summary: This movie begins with a definition of municipal sewage, where it goes, and the results of its discharge. It goes into great detail with "on location" scenes about the different types of sewage treatment plants. The movie then gives a basic outline of the steps a city or town must follow in planning the design, construction, and maintainance of a plant. A simple basis for choosing the most effective type of treatment is given, and summarizes the results the people can expect from their plant. The movie also goes into some detail about the operation of water treatment plants.

Appraisal: Since the movie is clear and easily understood in its description of sewage and its treatment processes it could be an effective way to inform the people of a town where a treatment plant is needed and of the decisions they will have to face. Though the movie is somewhat dated, it could be used early in a water pollution course.

Title: "The River Must Live"

Source: Shell Film Library, 450 North Meridian Street, Indianapolis Indiana 46204.

Information: Color, 21 minutes, Free loan

Summary: This film deals with the growth of industry as a cause of growth in pollution. The fact that one person's effluent is another's supply is mentioned. Processes of decay of life in the river through bacteria and the different forms of life contained within an ecosystem are discussed. The film speaks of how the pollutional imbalance decreases the supply of oxygen. There is a need for time in order to restore the natural balance. When there is too much pollution too close together, the river dies. After being dumped in the river, the pollution is carried to and lost in the sea's vastness. From there, through the hydrocycle, the water is renewed and returned to the land--a new chance and man's new, and quickly becoming only, hope. With different methods of waste treatment, which can renew the water before it reaches the sea, man has another hope. The film also treats the different uses of water--industrial, commercial, and domestic.

Appraisal: This film was rated very good to excellent. The narration was easy to follow, the organization was good, and the music was appropriate. There was excellent visual treatment of uses of water and different types of waste-water treatment. Also, the Shell Company refrained admirably from pushing their product. They did skim over the possibility of oceanic pollution ignoring the tertiary treatment factor. The best use of this film would be in water pollution as an introduction or just in-between.

E. Equipment

Various companies are selling commercial water testing equipment suitable for classroom use. Catalogs and descriptive literature can be obtained from the following addresses.

(1) Chemical testing equipment

(a) Hach Chemical Company
Box 907
Ames, Iowa 50010
(515) 232-2533

(b) Delta Scientific Corporation
120 East Hoffman Ave.
Lindenhurst, N.Y. 11757
(516) 884-4422

(c) LaMotte Chemical Products Company
Educational Products Division
Chestertown, Maryland 21620

(2) Bacteriological equipment

(a) Millipore Corporation
Educational Products Division

Bedford, Massachusetts 01730
(617) 275-8800

(3) Aquatic Biology Equipment

(a) Oceanography Unlimited, Inc.

108 Main St. Lodi, New Jersey 07644

(201) 779-2313

(b) Wildlife Supply Company

2200 S. Hamilton St.

Saginaw, Michigan 48602

(517) 753-1700

Appendix 6 Draft

Water Pollution and Environmental Glossary

This glossary is a compilation of terms from aquatic ecological, hydrologic and chemical fields of endeavor. Of the many persons who contributed, the principle contributor was John E. Mathews of the Department of Interior (Robert S. Kerr, Water Research Center, Ada, Oklahoma).

Terms underscored in a definition are separately defined in this Glossary. Where appropriate, closely associated or related terms are cited parenthetically, following the definition. Specific synoyms are noted in parentheses, with the listed word.

A

ABIOTIC FACTOR Physical, meteorological, geological, or chemical aspect of environment.

ABYSSAL ZONE All of a sea, or a very deep lake below the bathyal zone. The primary energy source for this region lies far above in the euphotic zone; density of life depends on the amount of organic material that settles from the euphotic zone. (See Hadal zone).

ACCLIMATION Physiological and behavioral adjustments of an organism in response to a change in environment. (See Adaptation)

ACCLIMATIZATION Acclimation of a particular species over several generations in response to marked environmental changes.

ACID An hydrogen ion (H^+) donor.

ACIDITY See Appendix 1: Chemistry

ACTINOMYCETES Filamentous microorganisms intermediate between the fungi and bacteria, although more closely related to the bacteria. These organisms are widely distributed in soils and are often conspicuous in lake and river muds. They are often associated with taste and odor problems in water supplies.

ACUTE TOXICITY Any toxic effect that is produced within a short period of time, usually 24-96 hours. Although the effect most frequently considered is mortality, the end result of acute toxicity is not necessarily death. Any harmful biological effect may be the result. (See Chronic Toxicity, Direct Toxicity)

ADAPTATION Change in the structure, form or habits of an organism to better fit changed or existing environmental conditions. (See Acclimation)

AEROBIC Refers to life or processes occuring only in the presence of free oxygen; refers to a condition characterized by an excess of free oxygen in the aquatic environment. (See Anaerobic)

ALGAE (Alga) Simple plants, many microscopic, containing chlorophyll. Algae form the base of the food chain in aquatic environments. Some species may create a nuisance when environmental conditions are suitable for prolific growth.

ALKALIINITY Appendix 1: Chemistry

ALLOCHTHONOUS Pertaining to those substances, materials or organisms in a waterway which originate outside and are brought into the waterway. (See Autochthonous)

ALLUVIAL FAN (Delta)

ANABOLISM Synthesis or manufacture of organic compounds within an organism. (See Metabolism)

ANADROMOUS Pertaining to fishes that spend most of their life in salt water but enter freshwater to spawn e.g., salmon, shad, striped bass, etc. (See Catadromous)

ANEROBIC Refers to life or processes occurring in the absence of free oxygen; refers to conditions characterized by the absence of free oxygen. (See Aerobic)

ANTAGONISM Reduction of the effect of one substance because of the introduction or presence of another substance; e.g., one substance may hinder, or counteract, the toxic influence of another. (See Synergism)

APHOTIC ZONE That portion of a body of water to which light does not penetrate with sufficient intensity to have any biological significance. (See Euphotic Zone)

ARTIFICIAL SUBSTRATE A device placed in the water (for a specified period of time) that provides living spaces for a multiplicity of organisms; e.g., glass slides, concrete blocks, multiplate samplers, rock baskets, etc. The primary purpose of artificial substrates is to allow the investigator to collect organisms in areas where the physical habitat is limiting or cannot be adequately sampled using conventional methods.

ASSIMILATION 1. Removal of dissolved or suspended materials from a water mass by biological, chemical and physical processes; 2. Conversion or incorporation of absorbed nutrients into body substances. (See Synthesis)

ASSOCIATION All organisms occupying a given habitat.

ATOLL Large, thick, coral mass encircling a lagoon in tropical oceans; sometimes portions of the reef become built up with sand, silt, soil and vegetation to become an island. (See Barrier Reef, Fringing Reef)

AUFWUCHS (Periphyton)

AUTOCHTHONOUS Pertaining to those substances, materials, or organisms originating within a particular waterway and remaining in that waterway. (See Allochthonous)

AUTOTROPHIC (Holophytic) Self nourishing; denoting those organisms that do not require an external source of organic material but can utilize light energy and manufacture their own food from inorganic materials; e.g., green plants, pigmented flagellates. (See Heterotrophic)

B

BARRIER BEACH A ridge of deposits separated from the mainland by an interval of water.

BARRIER REEF Large, think, coral mass more or less surrounding an island or paralleling the mainland shore in tropical areas; separated from the land mass by a lagoon. (See Atoll, Fringing Reef)

BASE An hydrogen ion (H^+) acceptor

BATHYAL ZONE That region of the sea that extends from the euphotic zone to the bottom of the continental slope. Density of life in this zone depends on organic material settling from the euphotic zone and is generally inversely proportional to the depth.

BEACH The zone of demarcation between land and water of lakes, seas, etc.; covered by sand, gravel or larger rock fragments.

BENTHIC REGION The bottom of a waterway; the stubstratum that supports the benthos.

BENTHOS Bottom-dwelling organisms. These include: (1) sessile animals such as sponges, barnacles, mussels, oysters, worms, and attached algae; (2) creeping forms such as snails, worms and insects; (3) burrowing forms, which include clams, worms, and some insects; and (4) fish whose habits are more closely associated with the benthic region than other zones; e.g., flounders.

BIOASSAY A determination of the biological effect of some substance, factor or condition employing living organisms or cells as the indicator.

BIOCHEMICAL OXYGEN DEMAND (See Appendix 1: Chemistry)

BIOCOENOSIS The plants and animals comprising a community.

BIOLOGICAL CONTROL 1. Use of natural predators, parasites or pathogens to reduce or eliminate pest organisms; e.g., use of gambusia to feed on mosquito larvae; 2. Control of organisms by interference with their physiological processes: e.g., sterilization of male flies.

BIOMASS The total amount of living material in a particular habitat or area; or, an expression dealing with the total weight of a given population of organisms.

BIOMONITORING 1. Continuous surveillance of an efflent (or dilution thereof) by using living organisms to test its suitability for discharge into a receiving water; 2. Use of living organisms to test the quality of a receiving water downstream from a waste discharge. (See Bioassay)

BIOTA All life of a region.

BIOTIC FACTORS (Biological Factors) In ecology, those environmental factors which are the result of living organisms and their activities; distinct from physical and chemical factors; e.g., competition, predation, etc. (See Ecological Factor)

BIOTIC POTENTIAL The inherent capability of an animal to multiply in an unrestricted environment. (See Environmental Resistance).

BIOTOPE (Habitat)

BLOODWORMS Midge fly larvae. Many of the species have hemoglobin in the blood causing a red color and are often associated with rich organic deposits. Also, the common name for certain of the marine segmented worms (class Polychaeta). (See Sludgeworms)

BLOOM A readily visible concentrated growth or aggregation of minute organisms, usually algae, in codies of water.

BRACKISH WATERS Those areas where there is a mixture of fresh and salt water; or, the salt content is greater than fresh water but less than sea water; or, the salt content is greater than in sea water.

BUFFER SOLUTION A solution which, within limits, resists changes in pH.

C

CHRONIC TOXICITY Toxicity, marked by a long duration, that produces an adverse effect on organisms. The end result of chronic toxicity can be death although the usual effects are sublethal; e.g., inhibits reproduction, reduces growth, etc. These effects are reflected by changes in the productivity and population struction of the community. (See Acute Toxicity)

CLASSIFICATION The placing or organisms into taxa (or categories) according to established scientific requirements. (See Taxonomy, Taxon)

CLEAN WATER ASSOCIATION An association of organisms found in any natural, unpolluted environment. These associations are characterized by the presence of species that are sensitive to environmental changes caused by introduction of pollutants. In many cases the presence of a wide variety of species with relatively few individuals representing any one of them is also characteristic. (See Sensitive Organisms, Toleratn Association)

CLINOMETER The standard instrument used by geographers to measure the slope of a hillside.

COASTAL PLAIN A plain between the sea and higher land, usually at a low elevation.

COASTAL WATERS Those waters surrounding the continent which exert a measurable influence on uses of the land and on its ecology. The Great Lakes and the waters to the edge of the continental shelf.

COASTAL ZONE Coastal waters and adjacent lands which exert a measurable influence on the uses of the sea and its ecology. The zone extends onshore to the upper reaches of the tidal zone and adjacent shore areas. (See Estuary)

COLD-BLOODED ANIMALS Animals that lack an internal temperature regulating mechanism to offset external temperature changes. Their body temperature fluctuates to a large degree with that of their environment. Examples are fish and aquatic invertebrates.

COLONY A distinguishable localized population witnin a species.

COMMUNITY All forms of life inhabiting a common environment.

COMPENSATION LEVEL The depth of a waterway at which there is a balance between photosynthesis and respiration.

COMPETITION The effort of two or more individuals or species of a community to utilize some of the same environmental resources.

COMPETITION EXCLUSION PRINCIPLE (Gause's Rule) No two species can occupy the same niche at the same time.

CONSUMERS Organisms which feed upon other organisms; often divided into first order consumers (Herbivores), second order (or higher) consumers (Carnivores which eat primary consumers), etc. (See Heterotrophic, Trophic Level)

CONTINENTAL SHELF The shallow, gently sloping portion of the sea bottom bordering a continent, down to a depth of about 200 meters.

CONTINENTAL SLOPE The steeply sloping portion of the seabottom extending seaward from the continental shelf.

CORAL A marine member of the phylum Coelenterata which secretes a hard exoskeleton, chiefly of calcium carbonate.

CORAL REEF Large coral mass associated with coastal areas in the tropics. (SeeBarrier Reef, Fringing Reef, Atoll)

CRITERIA (Water Quality Criteria)

CRITICAL LEVEL (Threshold)

CRITICAL RANGE In bioassays, the value range of any factor between the maximum level or concentration at which no organisms die to the minimum level or concentration at which all organisms die under a given set of conditions in a given period of time.

CULTURAL EUTROPHICATION Acceleration by man of the natural process of enrichment (aging) of bodies of water.

CULTURE Cultivation of organisms in a medium containing necessary nutrients.

D

DECOMPOSERS (Reducers)

DELTA (Alluvial Fan) A fan-shaped deposition of silt, sand, gravel or other materials from a stream. These occur when the hydraulic gradient lessens abruptly, as in the discharge of a stream into a lake, or a river into an ocean.

DENSITY (Population, Species) The number of individuals in relation to the space in which they occur; refers to the closeness of individuals to one another.

DENSITY STRATIFICATION (Stratification)

DEPOSITING SUBSTRATES Bottom areas where solids are being actively deposited. These often occur in the vicinity of elluent discharges. (See Sludge Deposits)

DETRITUS Fragments of detached or broken down material.

DIFFUSION The even mixing of one compound throughout another.

DIRECT TOXICITY Toxicity that has an effect on organisms themselves instead of having an effect by actual alteration of their habitat or interference with their food supply. (See Acute Toxicity, Chronic Toxicity, Indirect Toxicity)

DISSOCIATION The separation of pre-existing ions during the process of solution.

DISSOLVED OXYGEN (See Appendix 1: Chemistry)

DISSOLVED SOLID Any substance which existed primarily as a solid prior to the solution process.

DIURNAL 1. Refers to an event, process, or specific change that occurs every day; usually associated with changes from day to night. 2. Pertaining to those organisms that are active during day time. (See

Nocturnal)

DIVERSITY Pertaining to the variety of species within a given association of organisms. Areas of high diversity are characterized by a great variety of species; usually relatively few individuals represent any one species. Areas with low diversity are characterized by a few species; often relatively large numbers of individuals represent each species.

DOMINANT Species which by their activity, behavior, or number, have considerable influence or control upon the conditions of existence of associated species; species which "controls" its habitat and food web. (See Predominant)

DRIFT ORGANISMS Benthic organisms temporarily suspended in the water and carried downstream by the current. (See Incidental Drift, Periodic Drift, Catastrophic Drift.)

DYSTROPHIC LAKES Shallow lakes with brown water, high organic matter content, low nutrient availability, poor bottom fauna, and high oxygen demand; oxygen is continually depleted and pH is usually low. In lake aging the "age" between a eutrophic lake and a swamp.

E

EBB TIDE That period of tide between a high water and the succeeding low water; falling tide. (See Flood Tide)

ECOLOGICAL FACTOR Any part or condition of the environment that influences the life of one or more organisms. (See Biotic Factor)

ECOLOGICAL NICHE The role of an organism in the environment, its activities and relationships to the living and nonliving environment; food and nutrition relationships are of primary importance. (See Habitat Niche)

ECOLOGY Interrelationships between organisms and their environment, abiotic and biotic.

ECOSYSTEM A community, including all the component organisms, together with the environment, forming an interacting system.

ECOTYPE (Habitat Form) The growth form or appearance of an organism which is characteristic of a specific habitat. (Individuals of the same species may appear different in various habitats).

EMERSED (Emergent) AQUATIC PLANTS Plants that are rooted at the bottom of a body of water, but project above the surface; e.g., cattails, bulrushes, etc. (See Floating Aquatic Plants, Submersed Aquatic Plants)

ENDPOINT The point at which a titration is to be terminated, sometimes signifying the presence of equal amounts of reactants.

ENRICHMENT An increase in the quantity of nutrients available to aquatic organisms for their growth and development (See Eutrophication)

ENVIRONMENT All external influences and conditions affecting the life and development of an organism.

ENVIRONMENTAL RESISTANCE Restriction imposed on the numerical increase of a population by environmental factors. (See Biotic Potential)

EPILIMNION The water mass extending from the surface to the thermocline in a stratified body of water; the epilimnion is less dense than the lower waters and is wind-circulated and essentially homother mous. (See Hypolimnion)

EQUILIBRIUM 1. The condition in which a population or community is maintained with only minor fluctuations in composition over an extended period of time. Sometimes called Dynamic equilibrium. 2. A dynamic interaction of two opposing chemical or physical processes occuring at equal rates.

ESTUARY That portion of a coastal stream influenced by the tide of the body of water into which it flows: a bay, at the mouth of a river, where the tide meets the river current; an area where fresh and marine waters mix. (See Positive Estuary, Inverse Estuary, Neutral Estuary, Coastal Zone)

EULITTORAL ZONE (Tidal Zone)

EUPHOTIC ZONE The lighted region of a body of water that extends vertically from the water surfacr to the depth at which photosynthesis fails to occur because of insufficient light penetration.

EURY- Prefix meaning wide; e.g., euryhaline refers to a wide range of salinity tolerance; eurythermal refers to a wide range of temperature tolerance. (See Steno-)

EUTROPHIC LAKES Lakes which are rich in nutrients and organic materials, therefore, highly productive. These lakes are often shallow and seasonally deficient of oxygen in the hypolimnion. (See Oligotrophic Lakes)

EUTROPHICATION The natural process of the maturing (aging) of a lake; the process of enrichment with nutrients, especially nitrogen and phosphorus, leading to increased production of organic matter. (See

Cultural Eutrophication, Oligotrophic Lakes, Eutrophic Lakes)

EVAPOTRANSPIRATION The total of the transpiration of the plants of an area plus the evaporation of water from the area. Equals the total loss in the form of vapor.

F

FALCULTATIVE Refers to the capability of an organism to live under varying conditions; e.g., a falcultative anaerobe is an organism that although usually living in the presence of free oxygen can live in the absence of free oxygen. (See Obligate)

FALL OVERTURN A physical phenomenon that may take place in a body of water during early autumn. The sequence of events leading to fall overturn include: (1) cooling of surface waters, (2) density change in surface waters producing convection currents from top to bottom, (3) circulation of the total water volume by wind action, and (4) vertical temperature equality. The overturn results in a uniformity of the physical and chemical properties of the entire water mass. (See Spring Overturn)

FATHOM A unit of measurement equal to 6 feet (1.83 meters).

FAUNA Animal life

FECAL COLIFORM See Appendix 1: Bacteriology

FECAL STREPTOCOCCUS See Appendix 1: Bacteriology

FIRTH A narrow arm of the sea; also the opening of a river into the sea. (See Estuary)

FJORD (Fiord) A narrow arm of the sea between highlands. (See Firth, Estuary)

FLOATING AQUATIC PLANTS Rooted plants that wholly or in part float on the surface of the water; e.g., water lilies, water hyacinth and duckweed. (See Emersed Aquatic Plants, Submersed Aquatic Plants)

FLOOD TIDE That period of tide between low water and the succeeding high water; a rising tide. (See Ebb Tide)

FLORA Plant life.

FOOD CHAIN Dependence of a series of organisms, one upon the other, for food. The chain begins with plants and ends with the largest carnivores; e.g., phytoplankton - zooplankton - forage fish - game fish. Food chains usually don't exist in nature; they are parts of food webs.

FOOD CYCLE (Food Web) All the interconnecting food chains in a community.

FORAGE FISH Fish, usually smaller species, that are important as food for other species.

FREE-SWIMMING (Motile) Actively moving about in water or capable of moving about in water. (See Sessile)

FRINGING REEF Large coral mass at the edge of any land mass in tropical seas; it begins at the water's edge and may extend out to a quarter mile. (See Barrier Reef, Atoll)

G

GAME FISH (Sport Fish) Those species of fish considered to possess sporting qualities on fishing tackle; e.g., salmon, trout, black bass, striped bass, etc. Game fish are usually more sensitive to environmental changes than rough fish.

GAUSE'S RULE (Competition-Exclusion Principle)

GROUND WATER The body of water derived from percolation; contained in the woil, sub-soil and underlying rocks of an area.

H

HABITAT (Biotope) A specific type of place that is occupied by an organism, a population, or a community.

HABITAT FORM (Ecotype)

HABITAT NICHE The specific part or smallest unit of a habitat occupied by an organism. (See Ecological Niche)

HADAL ZONE Pertaining to that part of the ocean at depths exceeding 6000 meters, including both water and floor or bottom (See Abyssal Zone)

HERBIVORE An organism that feeds on plant material, a first order consumer. (See Carnivore)

HETEROGENEOUS Consisting of dissimilar elements or constituents. (See Homogeneous)

HETEROTROPHIC (Holozoic) Pertaining to organisms that are dependent on organic material for food. (See Autotrophic)

HIGHER AQUATIC PLANTS (Pond Weeds) Those plants whose seeds germinate in the water phase or substrate of a body of water and which must spend part of their life cycle in water. This grouping includes plants which grow completely submersed as well as a variety of emersed and floating leaf type.

HOLOPHYTIC (Autotrophic)

HOLOZOIC (Heterotrophic)

HOMOGENEOUS Of uniform composition throughout.

HOMOTHERMOUS Having the same temperature throughout.

HYDROLYSIS The reaction of a salt with water to produce a basic or acidic solution.

HYPOLIMNION The region of a body of water that extends from the thermocline to the bottom and is essentially removed from major surface influences. (See Epilimnion)

I

IDENTIFICATION The use of a taxonomic key or the equivalent to determine the scientific name of an organism.

INCIDENTAL DRIFT The casual, random drift of organisms. (See Drift Organisms, Catastrophic Drift, Periodic Drift)

INDICATOR 1. A substance which, by means of a color change, identifies the endpoint of a titration. 2. A substance which, by means of a color change, qualitatively and/or quantitatively evaluates the presence of an unknown substance.

INDIRECT TOXICITY Toxicity that affects organisms by interfering with their food fupply or modifying their habitat instead of directly acting on the organisms themselves. (SeeDirectToxicity)

INFILTRATION The term used by hydrologists to describe the gradual downward flow of water from the surface through soil to ground water and water table reservoirs.

INLET A short, narrow waterway connecting a bay, lagoon, or similar body of water with a large parent body of water; a stream which flows into a lake; an arm of the sea, or other body of water, that is long compared to its width, and that may extend a considerable distance inland.

INSTAR A stage in the life cycle of an insect or other arthropod between two successive molts.

INTERACTION Mutual or reciprocal action or influence between organisms, between organisms and environment, or between environmental factors.

INTERSPECIFIC Refers to relations or conditions between species. (See Intraspecific)

INTERTIDAL ZONE (Tidal Zone)

INTOLERANT ORGANISMS (Sensitive Organisms)

INTRASPECIFIC Refers to relations or conditions between individuals within a species. (See Interspecific)

INVERSE ESTUARY Type of estuary in which evaporation exceeds the supply of freshwater; evaporation > freshwater inflow + precipitation. (See Positive Estuary, Neutral Estuary)

INVERTEBRATES Animals without an internal skeletal structure; e.g., insects, mollusks, crayfish. (See Veterbrate)

ION An atom or group of atoms which has become charged either by loss or by gain of one or more electrons.

L

LAGOON 1. A shallow sound, pond, or channel near near or communicating with a larger body of water. 2. A settling pond for treatment of wastewater.

LARVA The immature form of an animal which is unlike its parents. Larva are usually self-feeding but must pass through some sort of metamorphosis before assuming the characteristics of the adult; in insects, the wormlike stage between the egg and the pupa.

LAW OF THE MINIMUM, LIEBIG'S "The growth and reproduction of an organism is dependent on the nutrient substance, such as oxygen, carbon dioxide, calcium, etc., that is available in minimum quantity." (See Limiting Factor)

LAW OF TOLERANCE, SHELFORD'S "When one environmental factor or condition is near the limits of toleration, either minimum or maximum, that one factor or condition will be the controlling one and will determine whether or not a species will be able to maintain itself." (See Limiting Factor)

LEACHING The process by which nutrients in the soil are dissolved and carried away by water flowing through it by processes such as percolation.

LENTIC Pertaining to standing (nonflowing) waters such as lakes, ponds, and swamps. (See Lotic)

LIFE CYCLE The various phases, changes, or stages through which an individual passes from the fertilized egg to death of the mature organism. Briefly stated it is birth-maturation - reproduction - death.

LIMITING FACTOR A factor whose absence, or excessive concentration, exerts some restraining influence upon a population through incompatibility with species requirements or tolerance. (See Law of the Minimum, Law of Tolerance)

LIMNETIC ZONE The open-water region of a lake, especially in areas too deep to support rooted aquatic plants. This region supports plankton and fish as the principal plants and animals. (See Littoral Zone)

LIMNOLOGY The ecology of fresh waters.

LITTORAL ZONE The shallow area that extends from shore to the lakeward limit of rooted aquatic plants; the shoreward region of a body o water; in marine ecology, the tidal zone. (See Limnetic Zone)

LOTIC Pertaining to flowing waters such as streams and rivers. (See Lentic)

M

MACROORGANISMS Those organisms retained on a U.S. standard sieve no. 30 (openings of o.589 mm.); those organisms visible to the unaided eye. (See Microorganisms)

MACROPHYTE Any plant that can be seen with the naked, unaided eye; e.g., aquatic mosses, ferns, liverworts, rooted plants, etc.

MEDIAN TOLERANCE LIMIT (TL_m) The concentration of tested substance in water at which just 50% of the test organisms survive for a specified period of exposure. (See Tolerance Limit)

MEROMICTIC LAKES Lakes in which dissolved substances create a gradient of density differerences with depth; this prevents complete mixing or circulation of water masses. (See Chemical Stratification)

MEROMIXIS A condition of permanent stratification of water masses i lakes.

MESOLIMNION (Thermocline)

10

METABOLISM The sum of all chemical processes occuring within an organism; includes both synthesis (anabolism) and breakdown (catabolism of organic compounds.

METALIMNION (Thermocline)

METAMORPHOSIS Distinct transformation of an animal from one distinctive life history stage to another in its postembryonic development; e.g., larva of an insect to a pupa. (See Life Cycle)

MICROORGANISMS Those organisms retained on a U.S. standard sieve no. 100 (openings of o.149 mm); those minute organisms invisible or only barely visible to the unaided eye. (See Macroorganisms)

MOLARITY A concentration unit which denotes the number of moles of particles (molecules or ions) present in 1 liter of solution.

MOLE A collective unit which signifies 6 x 10^{23} of anything but is used primarily when dealing with molecules or ions.

MOLT To cast or shed periodically the outer body covering which permits an increase in size. This is especially characteristic of invertebrates. (See Instar)

MOTILE (Free = Swimming)

N

NANOPLANKTON Very minute plankton not retained in a plankton net equipped with No. 25 silk bolting cloth (mesh, 0.03 to 0.04 mm.).

NATURAL SELECTION Processes occurring in nature which result in selective survival and eliminatiin of individuals less well adapted to their environment.

NAUPLIUS Free-swimming microscopic larval stage characteristic of many crustaceans, barnacles, etc.

NEAP TIDES Exceptionally low tides which occur twice each month when the earth, sun and moon are at right angles to each other; these usually occur during the moon's first and third quarters. (See Spring Tides)

NEKTON Macroscopic organisms swimming actively in water; e.g., fish. (See Plankton)

NERITIC ZONE Relatively shallow water zone which extends from the high-tide mark to the edge of the continental shelf.

NET PLANKTON Plankton retained in a plankton net equipped with No. 25 silk bolting cloth (mesh, 0.03 to 0.04 mm.).

NEUSTON Organisms associated with, or dependent upon, the surface film (air-water interface) of bodies of water.

NEUTRAL ESTUARY Type of estuary in which neither the freshwater inflow nor the evaporation predominates; freshwater inflow + precipitation = evaporation. (See Positive Estuary, Inverse Estuary)

NEUTRALIZATION The process of nullifying the effects of an acid (base) through the addition of a base (acid), usually accompanied by the formation of salt and water.

NICHE (See Ecological Niche, Habitat Niche)

NOCTURNAL Pertaining to those organisms that are active at night. (See Diurnal)

NUISANCE ORGANISMS (Pests) Those organisms capable of interfering with the use or treatment of water.

NUTRIENTS 1. Elements, or compounds, essential as raw materials for organism growth and development; e.g., carbon, oxygen, nitrogen, phosphorus, etc. 2. The dissolved solids and gasses of the water of an area.

NYMPH An immature developmental form characteristic of the preadult stage in insects that do not have a pupal stage; e.g., mayflies and stoneflies. (See Larva)

O

OBLIGATE Limited to one mode of life or action. (See Facultative)

OCEANIC ZONE The region of open ocean beyond the continental shelf.

OLIGOTROPHIC LAKES Deep lakes which have a low supply of nutrients, thus they support very little organic production. Dissolved oxygen is present at or near saturation throughout the lake during all seasons of the year. (See Eutrophic Lakes)

OMNIVOROUS Animal which is a first order consumer at some times and a second or higher order consumer at others. (See Herbivorous, Carnivorous)

OPTIMUM LEVEL The most suitable degree of an environmental factor for the full development of the organism concerned. (See Tolerance Range)

ORGANISM Any living individual.

OSMOREGULATION The adjustment in the osmotic concentration of solutes in body fluids in organisms to environmental conditions; e.g., when salmon migrate from salt to freshwater.

OVERTURN The period of mixing, (turnover) by top to bottom circulation, of previously stratified water masses. This phenomenon may occur in spring and/or fall; the result is a uniformity of physical and chemical properties of the water at all depths. (See Thermal Stratification, Chemical Stratification, Spring Overturn, Fall Overturn)

OXIDATION The loss of electrons by an atom or ion.

OXIDIZING AGENT A substance capable of accepting electrons from another substance and, therby, being reduced.

OXYGEN DEBT A temporary phenomenon that occurs in an organism when available oxygen is inadequate to supply the respiratory demand. During such a period the metabolic processes resutl in the accumulation of breakdown products that are not oxidized until sufficient oxygen becomes available.

OXYGEN DEFICIT The difference between observed oxygen concentration and the amount that would theoretically be present at 100% saturation for existing conditions of temperature and pressure.

P

PARASITE An organism that lives on or in a host organism during all or part of its existence. Nourishment is obtained at the expense of the host.

PATHOGEN An organism or virus that causes a disease.

PELAGIC ZONE The open sea, away from the shore. Comparable with the limnetic zone of lakes.

PERCOLATION Inflitration

PERIODIC DRIFT Drift of bottom organisms at regular or predictable intervals such as diurnal, seasonal, etc. (See Drift Organisms, Catastrophic Drift, Incidental Drift)

PERIPHYTON (Aufwuchs) Attached microscopic organisms growning on the bottom, or other submersed substrates, in a waterway.

PESTICIDE Any chemical preparation used to kill pests. Include insecticides, herbicides, fungicides, etc.

PESTS (Nuisance Organisms)

pH (See Appendix 1: Chemistry)

PHOTOSYNTHESIS The metabolic process by which simple sugars are manufactured from carbon dioxide and water by plant cells using light as an energy source. (See Chlorophyll)

PHOTIC ZONE (Euphotic Zone)

PHYTOPLANKTON The plants of the plankton. Unattached microscopic plants subject to movement by wave or current action. (See Zooplankton)

PLANKTON Suspended microorganisms that have relatively low powers of locomotion, or that drift in the water subject to the action of waves and currents. (See Benthos, Periphyton, Nekton)

POND WEEDS (Higher Aquatic Plants)

POOLS Areas of a stream, where the velocity of current is reduced. The reduced velocity provides a favorable habitat for plankton. Silts and other loose materials that settle to the bottom of pools are favorable for burrowing forms of benthos. (See Riffle)

POPULATION A group of interacting individuals of the same species, area, or community.

POSITIVE ESTUARY Coastal indentures in which there is a measurable dilution of sea water by land drainage; freshwater inflow + precipitation > evaporation. (See Inverse Estuary, Neutral Estuary)

POTAMON ZONE Stream reach at lower elevations characterized by reduced flow, higher temperature, and lower dissolved oxygen levels. (See Rithron Zone)

p.p.m. (Parts per million) A unit of concentration equivalent to the number of milligrams of solute in 1 liter of solution.

PRECIPITATE 1. A solid which separates from a solution because of some chemical or physical change. (noun) 2. (verb) The formation of such a solid.

PREDATOR An animal that kills and consumes other animals. (See Prey)

PREDOMINANT Those organisms that are of outstanding abundance in a particular community for a given period of time. (See Dominant)

PREY An animal that is dilled and consumed by another animal. (See Predator)

PRIMARY PRODUCTIVITY The total quantity of protoplasm produced by autotrophic organisms per unit of time in a specified habitat.

PRODUCERS Organisms that synthesixe organic material from inorganic substances; e.g., plants. (See Consumers, Reducers.)

PRODUCTION The process of producing organic material; the quantity produced.

PRODUCTIVITY 1. Rate of protoplasm formation or energy utilization by one or more organisms: total quantity of organic material produced within a given period in a specified habitat.

PROFUNDAL ZONE The deep, bottom-water area beyond the depth of effective light penetration. All of the lake floor beneath the hypolimnion.

PROLIFIC Pertaining to organisms that have a high reproductive potential and normally produce large numbers of young.

PROTOPLASM The living material in cells of plants and animals.

PUPA An intermediate, usually quiescent, form following the larval stage in insects, and maintained until metamorphosis to the adult stage. (See Larva)

Q

QUALITY A term to describe the composite chemical, physical, and biological characteristics of a water with respect to its suitability for a particular use.

QUIESCENT Refers to the temporary cessation of development, movement or other activity. (See Pupa)

R

RAPIDS Areas of a stream where velocity of current is great enough to keep the bottom clear of all loose materials, thus providing a firm substrate. The surface of the water is disrupted by turbulent currents. This area is occupied largely by specialized benthic or periphytic organisms that can firmly attach or cling to a firm substrate. (See Pools, Riffles)

RED TIDE A visible red-to-orange coloration of an area of the sea caused by the presence of a bloom of certain plankton. These blooms are often the cause of major fish kills.

REDD A type of fish spawning area associated with flowing water and clean gravel. Fishes that utilize this type of spawning area include trout, salmon, some minnows, et.

REDUCERS (Decomposers) Those organisms, usually bacteria or fungi, that break down complex organic material into simpler compounds. (See Producers, Consumers)

REDUCING AGENT A substance capable of releasing electrons to another substance and thereby, being oxidized.

REDUCTION The gain of electrons by an atom or an ion.

REEF A ridge of rocks, sand, soil or coral projecting from the bottom to or near the surface of the water.

RESPIRATION The complex series of chemical and physical reactions in all living organisms by which the energy and nutrients in foods is made available for use. Oxygen is used and carbon dioxide released during this process. (See Metabolism)

RIFFLES Fast sections of a stream where shallow water races over stones and gravel. Riffles usually support a wider variety of bottom organisms thatn other stream sections. Also called rifts. (See Pools, Rapids)

RITHRON ZONE Stream reach at higher elevations characterized by rapid flow, low temperature, and high dissolved oxygen levels. (See Potamon Zone)

ROUGH FISH Those species of fish considered to be of either poor fighting quality when taken on tackle, or of poor eating quality, e. g., carp, gar, suckers, etc. These fish are considered undesirable in most situations. Most species in the group are more tolerant of widely changing environmental conditions than game fish.

S

SALT MARSH Low area adjacent to the sea that is covered with salt tolerant vegetation and regularly flooded by the high tide; similar inland areas near saline springs or lakes, though not regularly flooded.

SAPROBIC Living on dead or decaying organic matter. (See Scavenger)

SAPROBICITY The sum of all metabolic processes which are the direct opposite of primary production; can be measured either by the dynamics of metabolism or analysis of community structure.

SAPROBIENSYSTEM European system of classifying organisms according to their response to organic pollution in slow moving streams. 1. Alpha-Mesosaprobic Zone - Area of active decomposition, partly aerobic, partly anaerobic, in a stream heavily polluted with organic wastes. 2. Beta-Mesosaprobic Zone - That reach of a stream that is moderately polluted with organic wastes. 3. Oligosaprobic Zone - That reach of a stream that is slightly polluted with organic wastes and contains the mineralized products of self-purification from organic pollution; but with none of the organic pollution remaining. 4. Polysaprobic Zone - That area of a grossly polluted stream which contains the complex organic wastes that are decomposing primarily by anaerobic processes.

SCAVENGER An organism that consumes decomposing organic matter.

SECONDARY PRODUCTIVITY Total quantity of animal (and other heterotrophic) protoplasm produced per unit of time in a specified habitat. (See Primary Productivity, Productivity)

SEDIMENT The material that settles to the bottom of a waterway.

SEEPAGE Any flow of ground water to the surface of the land. This can be in wells, springs, streams or in trickles of water we see in areas such as roadside cuts.

SEICHE Periodic oscillations in the water level of a lake or inland sea. These oscillations take place when a temporary local depression or elevation of the water level occurs.

SENSITIVE ORGANISMS (Intolerant Organisms) Organisms that exhibit a rapid response to environmental changes and are killed, driven out of the area, or as a group are substantially reduced in numbers when their environment is fouled. (See Tolerant Association)

SESSILE Pertaining to those organisms that are attached to a substrate and not free to move about; e.g., periphyton. (See Free-Swimming)

SESTON All material, both organic and inorganic, suspended in a waterway.

SLOPE The term used to describe the steepness of a hillside. It is often expressed in degrees (of an angle) or in per cent. A ten per cent slope means an increase in altitude of 10 feet for every 100 horizontal feet traveled.

SLUDGE DEPOSITS Accumulations of settled, usually rapidly decomposing, organic material in the aquatic system.

SLUDGEWORMS Aquatic segmented worms (class - Oligochaeta) that exhibit marked population increases in waters polluted with decomposable organic wastes. (See Bloodworms)

SPAWN 1. An aquatic animals, to produce or deposit eggs or sperm. 2. To produce eggs or young. 3. Eggs of fishes and higher aquatic invertebrates.

SPECIES (Both singular and plural) An organism or organisms forming a natural population, or groups of populations, that transmit specific characteristics from parent to offspring. Each species is reproductively isolated from other populations with which they might breed. Hybrids, the results of interbreeding, usually exhibit a loss of fertility.

SPORT FISH (Game Fish)

SPRING OVERTURN A physical phenomenon that may take place in a body of water during the early spring. The sequence of events leading to spring overturn include: (1) melting of ice cover, (2) warming of surface waters, (3) density changes in surface waters producing convection currents from top to bottom, (4) circulation of the total water volume by wind action, and (5) vertical temperature equality. The overturn results in a uniformity of the physical and chemical properties of the entire water mass. (See Fall Overturn, Overturn)

SPRING TIDE Exceptionally high tide which occurs twice per lunar month when there is a new or full moon, and the earth, sun, and moon are in a straight line. (See Neap Tides)

STANDARD (Water Quality Standard)

STANDING CROP The quantity of living organisms present in an environment at a selected point in time.

STENO- Prefix denoting a narrow range of tolerance of an organism to a specific environmental factor; e.g., stenothermal refers to temperature; stenohaline refers to salinity; etc. (See Eury-)

STIMULUS An influence that causes a response in an organism. (See Taxis)

STRATIFICATION (Density Stratification) Arrangement of water masses into separate, distinct, horizontal layers as a result of differences in density; may be caused by differneces in temperature, dissolved or suspended solids. (See Thermal Stratification, Chemical Stratification.)

SUBLITTORAL ZONE The part of the shore from the lowest water level to the lower boundary of plant growth; transition zone from the littoral to profundal bottom.

SUBMERSED (Submerged Aquatic Plants) Higher aquatic plants that grow, beneath the surface of the water; e.g., pondweed, coontails, etc.

SUBSTRATE The bottom material of a waterway; the base or substance upon which an organism is growing; a substance undergoing oxidation.

SUMMER KILL Complete or partial dill of a fish population in ponds or lakes during the warm months; variously produced by excessively warm water, by a depletion of dissolved oxygen, and by the release of toxic substances from a decaying algal bloom, or by a combination of these factors. (See Winter Kill)

SUPERSATURATION A condition in which a solution has more solute dissolved than is normally possible under the existing conditions.

SUPRALITTORAL ZONE (Supratidal Zone) The portion of the seashore adjacent to the tidal or spray zone.

SURFACE AQUATIC PLANTS (Floating Aquatic Plants)

SUSPENDED SOLID Any solid substance present in water in an undissolved state, usually contributing directly to turbidity.

SYMBIOSIS Two organisms of different species living in close association, one or both of which may benefit and neither is harmed.

SYNERGISM The joint action of two or more substances is greater than the sum of the action of each of the individual substances; e.g., action of certain combinations of toxicants. (See Antagonism)

SYNTHESIS The production of a substance by the union of elements or simpler chemical compounds.

SYSTEMATICS (Taxonomy)

T

TAXIS Directed movement by an organism in response to a stimulus; e.g., phototaxis is directed movement in response to a light stimulus; thermotaxis is directed movement in response to heat or cold as a stimulus; etc.

TAXON (Taxa) Any taxonomic unit or category of organisms; e.g., species, genus, family, order, etc.

TAXONOMY (Systemactics) Organism classification with reference to its relationship in the plant, animal, or protist kingdoms; includes the bases, principles, procedures and rules of classification.

TERRITORY The area which an animal defends against intruders.

THERMAL STRATIFICATION The layering of water masses owing to different densities in response to temperature. The condition of a body of water in which the successive horizontal layers have different temperatures, each layer more or less sharply differentiated from the adjacent ones, the warmest (or the coldest) at the top. (See Overturn)

THERMOCLINE (Mesolimnion, Metalimnion) The transition zone between the warm epilimnion and cold hypolimnion of stratified bodies of water; temperature change equals or exceeds 1°C for each meter of depth. (See Thermal Stratification)

THRESHOLD (Critical Level) The maximum or minimum duration or intensity of a stimulus that is required to produce a response in an organism.

TIDAL FLAT The sea bottom, usually wide, flat, muddy and nonproductive, which is exposed at low tide.

TIDAL MARSH A low, flat marshland that is intersected by channels and tidal sloughs, usually covered by high tides; vegetation consists of rushes, grasses, and other salt tolerant plants. (See Salt Marsh)

TIDAL ZONE (Eulittoral Zone, Intertidal Zone) The area of a shore between the limits of water level fluctuation; the area between the levels of high and low tides.

TIDE The alternate rising and falling of water levels, twice in each lunar day, due to gravitational attraction of the moon and sun in conjunction with the earth's rotational force.

TL_m (Median Tolerance Limit)

TOLERANCE Relative capability of an organism to endure an unfavorable environmental factor.

TOLERANCE LIMIT ($TL_{10...100}$) The concentration of a substance which some specified portion of an experimental population can endure for a specified period of time with reference to a specified type of response; e.g., TL_{100} means that all test organisms endured the stress for the specified time; TL_{10} means only 10% of the test organisms could tolerate the imposed stress for the specified time. (See Median Tolerance Limit)

TOLERANCE RANGE The range of one or more environmental conditions within which an organism can function; range between the highest and lowest value of a particular environmental factor in which an organism can live.

TOLERANT ASSOCIATION An association of organisms capable of withstanding adverse conditions within the habitat. This association is often characterized by a reduction in the number of species (from a clean water association) and, in the case of organic pollution, an increase in individuals representing certain species.

TITRATION The determination of the volume of a solution needed to reach with a known volume of sample, usually involving the progressive addition of the solution to the sample until the sample has reacted fully.

TOXICANT A substance that through its chemical or physical action, kills, injures, or impairs an organism; any environmental factor which, when altered, produces a harmful biological effect. (See Pesticide)

TOXICITY Quality, state or degree of the harmful effect resulting from alteration of an environment factor.

TOTAL COLIFORM (See Appendix 1: Bacteriology)

TRIPTON The dead suspended particulate matter in aquatic habitats; the nonliving portion of the seston. (See Detritus)

TROPHIC LEVEL One of the parts in a nutritive series in an ecosystem in which a group of organisms in a certain stage in the food chain secures food in the same general manner. The first or lowest trophic level consists of producers (Green Plants); the second level of herbivores; the third level of secondary carnivores. Most bacteria and fungi are organisms in the reducer (decomposer) trophic level.

TROPHOGENIC REGION The area of a body of water where organic production from mineral substances takes place on the basis of light energy and photosythetic activity.

TRANSPIRATION The photosynthetic and physiological process by which plants release water into the air in the form of water vapor.

TURBIDITY See Appendix 1: Chemistry

TURNOVER (Overturn)

U

UBIQUITOUS ORGANISMS Organisms that can tolerate a wide range of environmental conditions or variation; organisms that are so active or numerous as to seem to be present or existent in all types of environments. (See Tolerant Association, Sensitive Organisms)

UNICELLULAR Refers to an organism that consists of only one cell; e.g., blue green algae, protozoa, bacteria. These organisms may, however, be filamentous or colonial in form.

V

VERTEBRATES Animals that have an internal skeletal system. (See Invertebrate)

W

WATER QUALITY CRITERIA "A scientific requirement on which a decision or judgement may be based concerning the suitability of water quality to support a designated use." (See Water Quality Standard)

WATER QUALITY STANDARD "A plan that is established by governmental authority as a program for water pollution prevention and abatement." (See Water Quality Criteria)

WATERSHED The area of land delinated by the line separating areas of land, the water from which drains into separate river or stream sysems.

WATER TABLE The level of ground water of an area.

WINTER KILL The death of fishes in a body of water during a prolonged period of ice and snow cover; caused by oxygen exhaustion due to respiration and lack of photosynthesis. (See Summer Kill)

Z

ZONE An area characterized by similar flora or fauna; a belt or area to which certain species are limited.

ZOOPLANKTON The animals of the plankton. Unattached microscopic animals having minimal capability for locomotion.

The items below are arranged according to areas of application; the general comments apply to most areas.

A General Comments

1. When heating liquids or when working with acids, bases, or other caustic liquids, wear goggles or some other form of eye protection.
2. Show concern for others by not pointing the opening of a container (which you are heating or adding chemicals to) in the direction of fellow workers or their work.
3. Looking directly into containers which are being heated is very dangerous.
4. When such things as strong acids and strong bases are mixed with water or with each other, large amounts of heat are generated. Therefore, use pyrex containers and don't hold them in your hands. Leaving them unattended while they are still hot might cause injury to others.
5. Always pour acid into water, never water into acid.
6. If spillage occurs, turn off open flames and hot plates. Clean up spills immediately. The following procedure should be followed for cleaning up acids, bases, and other caustic substances.
   a. Get paper towels and a large beaker partially filled with water.

b. Grasp two or three folded paper towels from one end and daub and swab with the other end.

c. Place wet towels in the beaker.

d. When the liquid is cleaned up, wipe the area with a damp sponge or several thicknesses of wet paper towels.

e. Take beaker, wet paper towels, and sponge to sink and rinse with lots of water.

f. Squeeze wet paper towels and place in waste basket.

7. Acids, bases, caustic substances, and water samples which might be contaminated should not be pipetted by drawing the liquid into the pipette with your mouth. If a rubber bulb is not available, use a burette or a graduated cylinder.

8. Keep volatile liquids (alcohol, ether, petroleum derivatives, etc.) away from open flames.

9. The laboratory is a place of work. Playing around is wasteful of time, equipment, and supplies.

10. For the safety of yourself and other, label all containers which contain solid chemicals, liquids, etc.

"My uncle was a chemist
He isn't any more,
'Cause what he thought was H_2O,
Was H_2SO_4!"

11. Before leaving the laboratory, check your clothing for

spilled substances and thoroughly wash your hands.

B. Bacterial Studies

1. Treat all cultures as if they were pathogenic (disease causing).
2. Plastic and rubber should not be autoclaved.
3. Stay with the autoclave while it is in operation. Turn it off before you leave.
4. Keep work area and equipment sterile. This is necessary from a helath standpoint and to prevent contamination of your cultures.
5. Disposal of cultures and resterilization of plastic petri dishes can be accomplished as follows:
    a. Using forceps remove the petri dish covers, and then place covers, dishes, and cultures into a large beaker or pan containing undiluted, liquid household bleach.
    b. After 10 minutes remove the petri dishes, using tongs or a rubber glove, and rinse them well under running water. The wet pads and filter should be put into a plastic bag and discarded.
    c. Immerse the petri dishes and covers in a solution of 70% isopropyl (rubbing) alcohol for 10 minutes.
    d. Remove the petri dishes and covers and stack on a clean surface. Then assemble the dishes and covers. (They are now ready for re-use.)

C. Chemistry

1. Testing chemicals is dangerous and rarely leads to conclusive results.
2. Should the occasion areise for smelling gases given off by chemical reactions, waft the rising gases to your nose with gentle sweeps of the hand.
3. To avoid sudden dangerous situation from occuring, plan your activity in advance.
4. Always read and re-read lables. Particularly note cautions on labels.
5. When connecting rubber and glass apparatus, lubricate the glass with water and assemble with a twisting motion.
6. Be careful when heating or cooling chemicals; be sure the container is designed to be heated. Graduated cylinders and bottles usually are not designed to withstand rapid temperature changes.

D. Field Trips

1. Be sure to take a first-aid kit on all field trips.
2. Wear appropriate clothing. Use old sneakers when wading in unknown waters and swamps.
3. If you are going to be using boats in deep water assure that everyone has a life jacket or other floatation devices.
4. Pair off when working in situations where drowning may occur

5. Plan for emergency services by obtaining phone numbers of appropriate services in the field area.

Revision. During the 1970-1971 school year, constant feedback concerning this learning guide must be obtained to assure that the June 1971, final copy will be of optimum use for water pollution and environmental studies. Each person receiving this guide should feel obligated to provide comments and suggestions for its improvement.

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The importance of your suggestions cannot be overly stressed. The quality and usefulness of the learning guide when it is released nationwide will be directly related to each of your comments.